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John R. Baldwin, Desmond Beckstead, Naginder Dhaliwal,
René Durand, Valérie Gaudreault, Tarek M. Harchaoui, Judy Hosein,
Mustapha Kaci, Jean-Pierre Maynard

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Preface

Statistics Canada's productivity program was initiated in the late 1940s. It was the result of recommendations from an interdepartmental committee on productivity analysis, who reviewed the conceptual and measurement problems involved and the available data sources in Canada.

The productivity measures were built on the Canadian System of National Accounts. The productivity program introduced statistical series of output per person employed (i.e., labour productivity) for the commercial (non-agricultural) sector, and its manufacturing and non-manufacturing components.

Initially, labour productivity estimates were the only product. They were of particular interest in labour negotiations between workers and management, where wage-rate increases were sometimes based on average labour productivity gains. They were also of interest to those studying how growth in labour productivity played a vital role in improving real living standards.

By the mid-1970s productivity growth trends had slowed dramatically. A flurry of research studies aimed at explaining the slowdown focused on issues and concepts that went beyond labour productivity. Statistics Canada recognized the desirability of extending its labour productivity program to encompass additional inputs and other innovations coming from recent developments in production theory. Following a feasibility study in the early 1980s, the multifactor productivity program was launched in 1987 as a regular statistical program.

As a result of these major developments, Statistics Canada has published annual indices of multifactor productivity, labour productivity and related measures for broad economic sectors and for more than 100 two- and three-digit 1980 Standard Industrial Classification (1980 SIC-E) business sector establishments (1961 to the present).

This publication adds to our knowledge of productivity measures in Canada by

- providing information on productivity performance in Canada at various levels of industry detail;
- demonstrating how productivity measures are constructed, what their underlying assumptions are, and to what extent estimates may be subject to measurement errors; and
- showing how productivity measures can be used for analytical purposes.

Stewart Wells
Assistant Chief Statistician
National Accounts and Analytical Studies

Introduction

Productivity Growth in Canada is designed to provide a comprehensive guide to analysts, researchers, students and consultants who wish to carry out research with and to interpret productivity measures in Canada.

The publication includes an overview of the standard productivity growth measures, data construction procedures and measurement issues. It considers in detail a number of underlying theoretical concepts and measurement issues. It goes further, however, by illustrating how productivity measures and related economic performance indicators can be used and interpreted.

In addition, a number of empirical studies are included that extend our understanding of uses to which productivity measures can be put. More specifically, in the empirical work, emphasis is placed on the use of microdata and country of control characteristics to examine productivity changes at the firm level. Furthermore, attempts are made to consider the importance of economies of scale, fixity and market power when measuring productivity growth. The publication also devotes special attention to the issue of capital formation, identified by many researchers as an important determinant of economic growth.

The chapters are organized as follows:

a) The first chapter provides an overview of the concepts of both labour and multifactor productivity growth. It also summarizes the trends in productivity performance over the last four decades. The relationship between labour productivity and economic well-being is also discussed.

b) The second chapter considers how productivity growth affects the economy. Two main issues are addressed. The first is the extent to which Canada has been shifting production away from sectors with low productivity to those with higher productivity. The second asks whether and how productivity growth influences structural change. The chapter finds that productivity gains are primarily passed on to consumers via changes in prices, rather than to workers in terms of relative wage changes.

c) The third chapter discusses the types of confidence intervals that should be employed by users of productivity estimates. The chapter highlights the need for statistical indicators that will provide a measure of the reliability of productivity measures to data users. In doing so, it identifies several ways of assessing the boundaries that should be placed around the point estimates of productivity growth—ranging from classical estimation techniques to comparisons of productivity growth rates based on alternate estimation techniques for capital stock. It also discusses problems in international comparisons that use employment rather than hours-worked as a measure of labour input. Based

on the differences in the results of these different techniques, it notes that conclusions about changes in productivity trends and differences across countries need to be made cautiously.

d) The fourth chapter discusses differences in productivity growth between Canada and the United States. The chapter examines differences in methodological techniques used in the two countries and then compares the estimates that are produced by Statistics Canada and by the Bureau of Labor Statistics. It finds a close relationship between the two economies for the overall business sector but differences for the manufacturing sector. In the latter area, the largest differences are in computers and electronics. It also examines the effect of making changes to the estimation techniques of both countries that reduce the differences in the methodologies used.

e) The fifth chapter focuses on micro-data and examines labour productivity differences between domestic and foreign-owned firms in the manufacturing sector. This chapter uses micro-data on individual establishment performance to study differences in the growth of labour productivity between domestic and foreign-controlled establishments in the manufacturing sector for the period 1973 to 1993. In doing so, it also examines the extent to which differences exist between small and large establishments and across industry sectors and how they have been changing over time. Foreign-controlled establishments are shown to have higher labour productivity and the highest growth rates over time in labour productivity. In addition, labour productivity has been growing more quickly in large plants than small plants.

f) The sixth chapter focuses on the history of investment and the extent to which the mix between machinery as opposed to buildings and structures has changed over the last twenty years. Since the mid-1980s, the national savings rate has averaged just over 18% of GDP, compared with 24% during the 1960s. One explanation for slower productivity growth since 1975 is that this lower savings rate has constrained investment and thereby deprived the nation of both the tools and the technologies it needs. The chapter shows that the types of private domestic investment in machinery and equipment that determine productivity have fallen less than one might infer from the decline in overall savings. The chapter also notes that capital stock per unit of labour is rising in Canada, but not as fast as in the past. The slower growth of the capital-to-labour ratio is not the result of a restructuring from goods to services.

g) The seventh chapter examines the cyclical behaviour of the labour productivity series. It asks whether the slowdown in growth during the post-1973 period is accompanied by increasing volatility. This chapter uses simple summary statistics to analyse the volatility, persistence, and co-movement of 37 industrial labour productivity series for the period 1961-1996. It seeks to identify the size, source, and correlation of fluctuations in the productivity performance of specific industries within various sample periods and to analyze possible changes in these characteristics over time. It finds that productivity growth in the post-1973 period has become more volatile, that changes have become more persistent, and that the importance of common factors behind these changes has also increased.

h) The eighth chapter provides alternate, experimental estimates of productivity growth that are based on a different methodology than the non-parametric technique that is normally used. It uses parametric multivariate analysis to

estimate multifactor productivity growth rates that allow for scale economies and capital fixities. The principal findings are that the normal assumptions used to estimate productivity—that markups are non-zero, that excess capacity generally exists, and that there are constant returns to scale—are incorrect, but that relaxing these assumptions has a relatively small effect on the productivity estimates. It finds that the assumption of constant returns to scale and full capacity tends to decrease the estimate of productivity change by roughly 30% over the period 1961 to 1995, but that the estimate of this 'bias' is not very precise.

i) Appendices 1 to 5 provide productivity estimates, their underlying sources, concepts and methods, and their availability on Cansim.

1 Productivity: Concepts and Trends

John R. Baldwin, Tarek Harchaoui, Judy Hosein and Jean-Pierre Maynard

1.1 Introduction

Productivity is one of several key indicators of the health of an economy. It provides an indication of the productive capability of the economy by measuring how much output an economy produces for a specific amount of resources that it devotes to production.

In the past few years, the productivity of Canadian industries has been the focus of sustained attention. There has been a major slowdown in productivity growth since the prosperous 1960s. Many analysts have tried to explain the causes of this slowdown and its effects on Canada's economy, using measures of both labour and multifactor productivity. This chapter compares the two measures and their trends in recent years. It also examines the relationship between productivity and economic well-being.

1.2 Definition and measurement

Productivity is a measure of the productive capability or efficiency of an economy. It can be defined in terms of a level—how much output is produced per unit of input (e.g., output per worker)—or in terms of a growth rate—the increase in output per worker. Statistics Canada focuses on the growth rate in productivity because of its usefulness in understanding the extent to which improvements in productivity contribute to economic growth.

Economic growth arises from an increase in the quantity of goods and services produced by a country in a given period. The two main sources of economic growth in output are increases in the factors of production (the labour and capital devoted to production) and efficiency or productivity gains that enable an economy to produce more for the same amount of inputs. Increases in productivity may come from many sources: technological progress, economies of scale (firms get larger and more efficient), research and development, and increases in the quality of the inputs that go into the production process. These changes occur on the shop floor.

Measurement of efficiency gains due to productivity growth are derived by subtracting the contribution of the additional quantities of inputs used between two periods from the change in quantity produced. The result, a measure of productivity growth, is the residual portion of growth that cannot be accounted for by the additional quantities of inputs that have been used to produce the increase in outputs observed.

Productivity growth, then, captures the economy's progress in improving its capability of producing output as more inputs are devoted to production. Being able to get more from less tells us, *mutatis mutandis*, about the rate of technological change. In the long term, this productivity measure, because of the way it is calculated, represents the improvement in the efficiency with which a business, industry, or country produces goods and services. In this sense, increased productivity is a key element in improving our economic well-being because, without it, the rate of increase in output would be the same as the increase in the factors of production used.

Two measures of productivity growth

Productivity growth can be measured as the increase in output relative to the increase in a single input like labour (growth in labour productivity) or the increase in output relative to the increase in a bundle of inputs like labour and capital (growth in multifactor productivity).

Labour productivity growth is the most widely used measure. This productivity measure captures the increase in the quantity of goods and services produced per unit of labour (hours worked).[1] It measures the increase in the

[1] Its counterpart is capital productivity—the ratio of output to capital. This measure receives less attention than does labour productivity.

productive capacity of the economy relative to employment. Labour productivity growth is intuitively meaningful since it measures the growth in how much workers are able to produce. It is also of empirical interest since gains in real wage rates closely track gains in labour productivity, as will be shown in Chapter 2.

Output per hour worked or labour productivity is affected by the amount of capital—machinery, equipment and buildings—that is provided to workers. Plants that have more capital tend to have a higher output per hour worked. It is useful to know why labour productivity increases—whether it is because capital per worker increases or because technological changes occur that are unrelated to changes in capital intensity. Towards this end, Statistics Canada also produces a multifactor productivity measure.

Analogous to the concept of labour productivity, multifactor productivity measures the amount of output produced by a standard input bundle that is made up of labour and capital. The *growth* in multifactor productivity refers to the *change* in output relative to the *change* in a bundle of inputs—labour and capital.[2] Since it measures the residual growth not due to both labour and capital growth, it is more comprehensive than just the labour productivity measure—but it may be less accurate because of the complexity of measuring the capital stock.[3]

In summary, a labour productivity growth measure tracks changes in output per hour worked, whereas a multifactor productivity growth measure captures the increase from the growth in production minus the increase of inputs that are devoted to the production process. For example, if output increases by 6% annually and inputs increase by 5%, multifactor productivity increases by 1%.

It should be noted that the two productivity measures are related algebraically.[4] Multifactor productivity growth can be expressed as a weighted average of labour and capital productivity growth:

$$\text{Multifactor productivity} = \alpha^*(\text{labour productivity}) + \beta^*(\text{capital productivity}) \qquad (1)$$

where α and β are the share of GDP in current dollars that goes to labour and capital, respectively.

This formula can be rewritten to express labour productivity growth as a function of the growth in multifactor productivity and the capital-to-labour ratio:

$$\text{Labour productivity} = \text{multifactor productivity} + \beta * (\text{growth in capital/hour}) \qquad (2)$$

Labour productivity growth, then, is equal to multifactor productivity growth plus the growth in capital/labour intensity multiplied by capital's share of output. Labour productivity growth will exceed multifactor productivity growth when the capital-to-labour ratio is increasing.

This brief summary has focused on what productivity measures capture. It is also important to stress what they do not measure, since productivity growth is sometimes confused with other important economic measures.

Productivity growth does not necessarily mean that profits and wages have increased. For example, a firm may increase the efficiency of its production process, but if the price for its product falls, it will see profits decline and may be forced to pay its workers less to remain in business. The same can happen for a nation. Productivity can go up, but less can be left for workers' wages if prices have fallen. Canada can produce raw materials more efficiently than anyone else in the world, but if prices of raw materials are falling relative to other products, profits and wages may stagnate despite robust productivity growth. Of course, the reverse can also occur.

Further, productivity growth is not necessarily synonymous with growth in general. High output growth may be associated with low or high productivity growth.

Productivity growth, then, is just one measure that needs to be used in conjunction with others in order to evaluate the state of an economy.

1.3 Trends in labour productivity growth and multifactor productivity growth

Labour productivity in the business sector[5] has generally experienced a higher rate of growth than multifactor productivity (Figure 1.1). Since 1961, labour productivity has

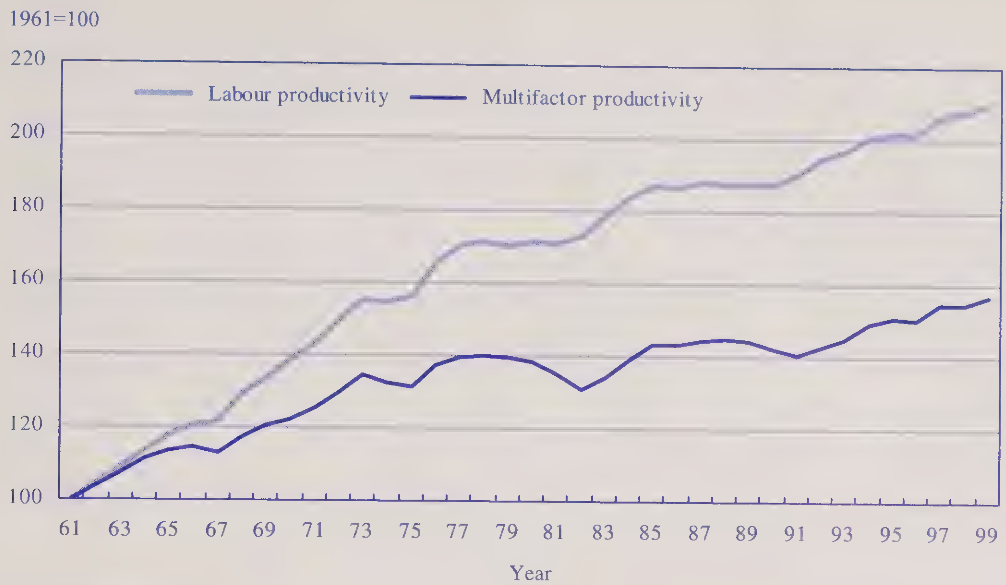
[2] This definition applies when output is defined as value added. When output is defined as gross output the bundle of inputs includes labour, capital and materials. See Appendix 1 for a discussion of these various concepts.

[3] See Chapter 3 for a discussion of measurement problems associated with productivity estimates.

[4] For a discussion of the relationship between multifactor and labour productivity measures, see Appendix 1.

[5] Statistics Canada's productivity indices cover the business sector – the economy less those sectors that are primarily non-profit. For further definitions, see Appendix 1.

Figure 1.1 Cumulative multifactor productivity growth[1] and labour productivity growth for the business sector, 1961-1999



Note: 1. Based on value-added measure.

grown at an average annualized rate of 2.0%. This compares with an average annualized rate of 1.2% for multifactor productivity. The difference between these two is explained by an increase in the capital-to-labour ratio over the period 1961-1999. Since the early 1960s, Canadian businesses have become far more automated. This has meant a steady increase in the quantity of capital per worker. Faster growth in labour productivity surpassed growth in multifactor productivity in large measure because the amount of capital per worker has been increasing.

Short-run productivity estimates

Annual estimates of productivity growth are highly variable over time (Figure 1.2). This occurs because inputs are not adjusted to changes in output quickly. Increases in demand may be unanticipated, and firms may not be able to increase their factor inputs as rapidly as desired. Similarly, decreases in output may not be accompanied by rapid adjustments in factor inputs.

Reducing capital inputs during a recession occurs slowly. Businesses rarely discard capital stock during an economic slowdown; rather, they tend to decrease the intensity of its use. Also, since investment decisions are made well in advance, capital stock usually continues to increase in the early part of a recession, when production starts to decline.

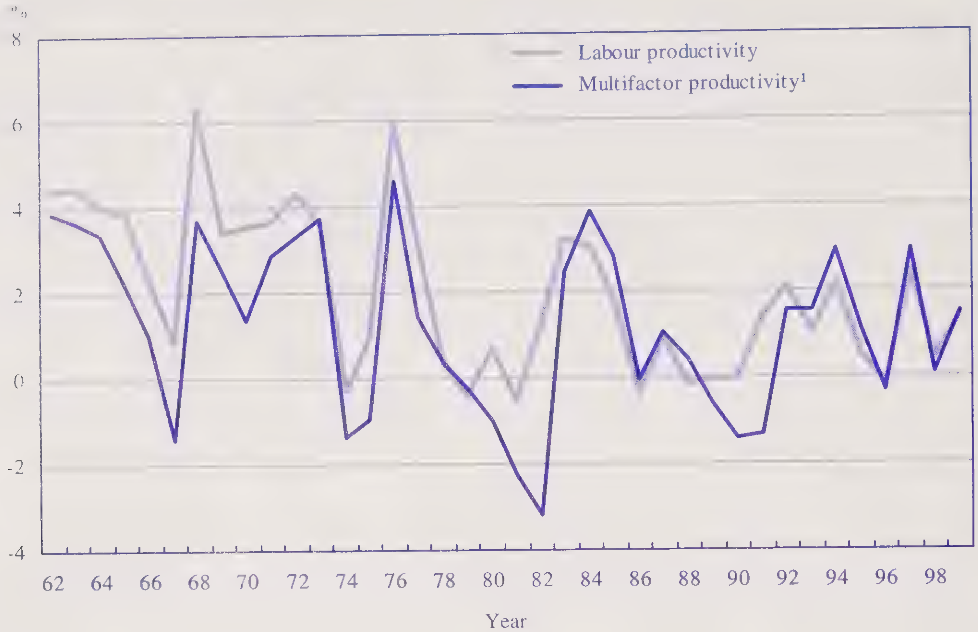
Labour inputs also have some of the characteristics of fixed inputs. Where special skills have been imparted to the work force by on-the-job training, firms are reluctant to lose employees by laying them off. Despite this, adaptation of employment to changing demand is generally regarded as occurring more readily than the adaptation of capital stock. In a recession, firms do discharge workers, although not proportionately to the decline in output. Similarly, in a recession, some capital may be discharged, but most is kept in abeyance until demand turns around and begins to grow again.[6]

As a result, there are large fluctuations in the annual or short-run productivity estimates, especially during downturns of the business cycle. The labour productivity estimates have about the same variance as the multifactor productivity estimates—with standard deviations of 1.9 and 2.0 percentage points, respectively. However, the coefficient of variation (the ratio of the standard deviation to the mean) is lower for labour productivity than for multifactor productivity—at 0.9 and 1.6, respectively.

The volatility in these estimates means that changes in longer-run trends are difficult to detect in the short run. An evaluation of the performance of productivity is best done using data over longer periods, such as from peak to peak of an economic cycle. For instance, the calculation

[6] Variations in capital utilization are taken into account when estimating multifactor productivity by calculating the capital share on an annual basis. In a recession, this share declines.

Figure 1.2 Volatility of productivity series, annual growth rates, 1962-1999



Note: 1. Based on value-added.

of the productivity performance is understated in the 1990s, if 1988 is used as a starting point and the early years of the 1990s are used as an end point (peak to trough). In the same vein, reading too much into any particular year's productivity estimate is risky because high levels of growth in one period are often followed by low growth in the next. It is the long-term growth of productivity over a cycle that is most meaningful in terms of understanding growth trends.

Long-term trends

Since 1961, the Canadian economy has gone through four cycles of productivity growth: from 1966 to 1973; from 1973 to 1979; from 1979 to 1988; and from 1988 to 1999. Long-term trends in both the multifactor and the labour productivity index confirm that the productivity growth rate has been slower in recent years than in the period prior to 1973. Figure 1.3 shows the average multifactor and labour productivity growth rates for these four economic cycles.[7] Prior to 1973, labour productivity grew by 3.7%. In the post-1973 period, labour productivity experienced lower rates of growth in all subsequent cycles ranging from 1.6% in the 1973-1979 cycle to 1.0% in the 1988-1999 cycle. Similarly, multifactor productivity growth was 2.3% prior to 1973 but only 0.6%, 0.4%, and 0.7% in the subsequent three cycles. Multifactor productivity growth rates have been more or less steady for the last three cycles, though much lower than in the period prior to 1973.

Figure 1.3 Multifactor productivity and labour productivity, average growth rates, selected periods

Note: 1. Based on value-added.

1.4 Sources of growth

As was explained in Section 1.2, the multifactor productivity index based on GDP is produced from an accounting exercise that decomposes the sources of output growth into three components: productivity growth, capital growth and labour growth. In Table 1.1, the rate of growth in output is divided into growth from increased labour inputs,

[7] The last cycle in the 1990s is not complete.

Table 1.1 Annualized rates of growth of output[1] and contributions by type of input, selected periods

	1961-99	1961-66	1966-73	1973-79	1979-88	1988-99
			%			
Business Sector						
Output	3.8	6.9	4.9	3.5	3.1	2.5
Contribution of Capital	1.4	1.5	1.6	1.6	1.5	1.0
Contribution of Labour	1.2	2.4	1.0	1.3	1.2	0.8
Multifactor Productivity	1.2	2.9	2.3	0.6	0.4	0.7
Services						
Output	4.3	6.2	5.6	4.7	3.7	3.0
Contribution of Capital	1.5	1.6	1.5	1.6	1.6	1.4
Contribution of Labour	1.9	2.7	1.8	2.3	2.0	1.4
Multifactor Productivity	0.9	1.9	2.3	0.8	0.2	0.2
Goods						
Output	3.2	7.4	4.2	2.4	2.5	1.8
Contribution of Capital	1.3	1.5	1.7	1.6	1.4	0.5
Contribution of Labour	0.5	2.2	0.3	0.3	0.4	0.1
Multifactor Productivity	1.5	3.7	2.3	0.5	0.6	1.2
Manufacturing						
Output	3.7	8.9	4.9	2.5	2.5	2.3
Contribution of Capital	0.9	1.3	1.4	0.6	0.9	0.7
Contribution of Labour	0.6	2.9	0.7	0.2	0.2	0.0
Multifactor Productivity	2.2	4.6	2.7	1.7	1.4	1.6

Note: 1. Based on value-added.

increased capital inputs, and residual growth from productivity improvements. The contribution made by labour and capital is just the rate of growth of each of these inputs weighted by their respective income shares. For example, over the period 1961 to 1999, business sector output grew by 3.8% annually. Of this, 1.2% came from labour growth, 1.4% from capital growth, and the residual (1.2%) was productivity growth.

The annual growth of output has varied considerably over the period. At 6.9% per year, it was highest in the first period, 1961-1966, but it steadily declined to 2.5% in the 1988-1999 period. Throughout the first four periods, capital growth made about the same contribution to total growth—1.5% to 1.6%. Labour's contribution was highest in the first and fastest-growing period at 2.4%. It dropped to about 1% in the 1970s and 1980s. Since 1966, labour growth has contributed less to overall growth than has capital growth.

Multifactor productivity growth was much more important in the first two periods—at 2.9% and 2.3%, respectively. However, its contribution to output growth in the last three periods was lower than before 1973. Labour productivity growth in the last three periods was also significantly lower than in the period prior to 1973.

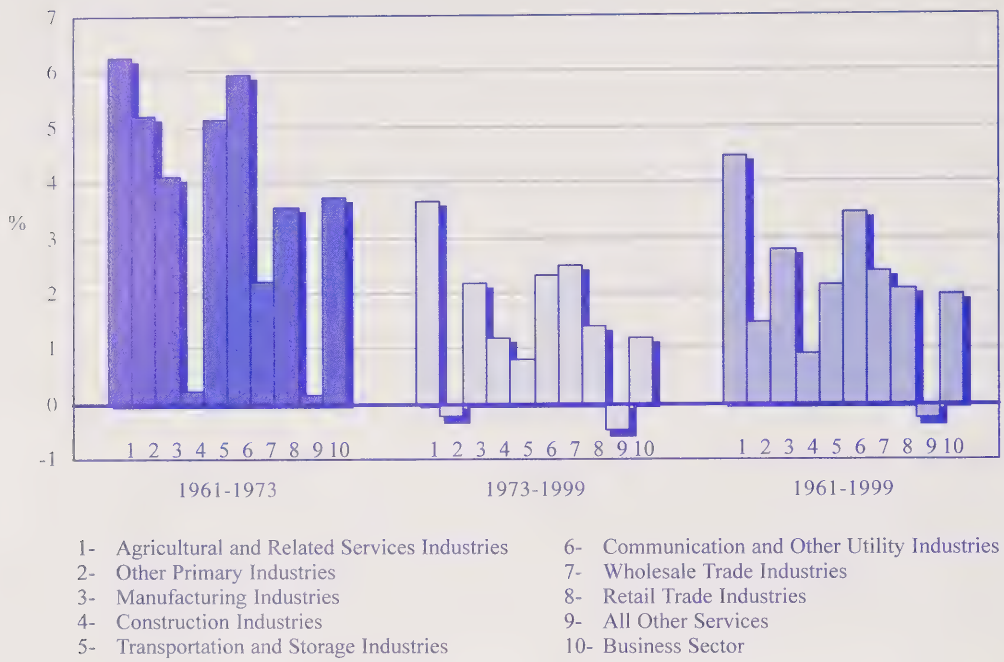
It is important to note that the economy exhibited slower overall growth during the 1990s as compared with the 1970s and 1980s. This was not because multifactor productivity growth declined rapidly, but because growth in employment and capital declined at a faster rate than growth in multifactor productivity *per se*. Over the historical period 1961 to 1999, the contribution of multifactor productivity to the growth of output in the business sector was equal to that of labour and capital (approximately 32%). However, productivity played a larger role in the growth of the output of the Canadian business sector during the period 1966-1973, when it accounted for 47% of output growth. This contribution fell to about 15% in the 1970s and 1980s, and increased in the latest period (1988-1999) to 28%.

The main source of output growth varies by sector. In the services-producing sectors, labour was the engine of output growth, with a contribution of close to 50% in the post-1973 periods. By contrast, in the goods-producing sector, capital was the most important source of growth, contributing over 50% during the 1973-1979 and 1979-1988 periods.

1.5 Industry performance

The level of productivity growth for the business sector as a whole depends on the rates of growth in the underlying sectors that make up the economy. The rate of technological change is not the same in all sectors. New technologies and changes in organizational structures that increase productivity are more amenable to application in some industries than others.

Figure 1.4 Labour productivity by industry group, annualized growth rates, selected periods



To illustrate these differences, the growth in labour productivity by industry is depicted in Figure 1.4 for the periods before and after 1973. Agriculture, manufacturing, and communications were among the leaders in both periods and, as a consequence, were also among the leaders over the entire time period. In contrast, other primary industries experienced very rapid growth only in the first period, and wholesale trade industries experienced relatively rapid growth only in the second period.

A similar pattern emerges when multifactor productivity is tabulated by industry (Figure 1.5) Once again, agriculture, manufacturing, and communications are among the leaders.

Much has been made of the impact of productivity increases in agriculture. Over this century, these increases have allowed an urban society to develop. The large increases in agricultural productivity in the early 1900s meant that a large urban work force could be supported by a smaller and smaller farm population. The large productivity increases of the agriculture sector in the pre-World War II period have continued into the present. Since the 1960s, the agriculture sector has been one of the leaders in terms of productivity gains.

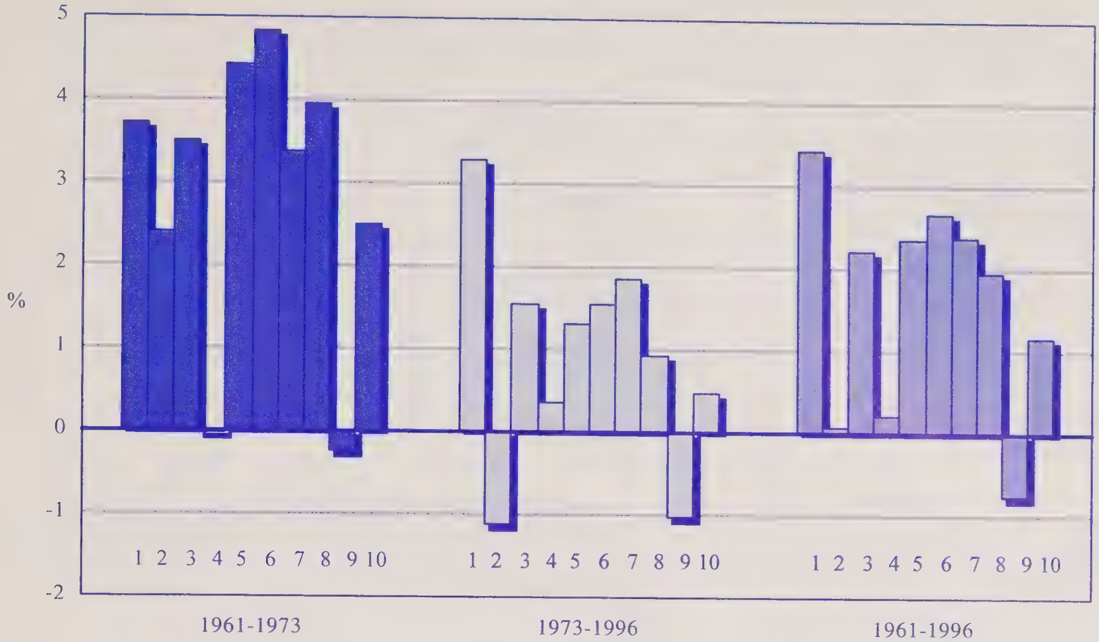
Transportation systems have also produced high productivity gains. New generations of jet aircraft have led to increases in productivity in the airline industry, whereas transportation deregulation and new diesel systems have influenced productivity in the rail industry.

At the same time, the communications industries have experienced dramatic growth in productivity. As new technologies have been introduced, the cost of telephone messages has fallen. Productivity growth in this industry has been just as high as that in the transportation sector.

The two distribution systems (retail and wholesale) have also had relatively high rates of productivity growth. These gains occurred as inventory distribution systems were made more efficient, and as larger stores were constructed.

Despite these gains in the service sectors, strong productivity performance in manufacturing has continued. In this sector, new computer-based technologies in design and engineering, fabrication and assembly, communications, and integrated control processes have improved productivity performance.

Figure 1.5 Multifactor productivity[1] by industry group, annualized growth rates, selected periods



1- Agricultural and Related Services Industries
2- Other Primary Industries
3- Manufacturing Industries
4- Construction Industries
5- Transportation and Storage Industries
6- Communication and Other Utility Industries
7- Wholesale Trade Industries
8- Retail Trade Industries
9- All Other Services
10- Business Sector

Note: 1. Based on value-added.

The relative contribution of productivity growth in selected industries to overall aggregate productivity growth is presented in Figure 1.6 for the period 1961 to 1995 along with the relative importance of each sector as measured by its share of value added. The contribution to aggregate productivity growth is measured by weighting the productivity growth of each industry grouping by its nominal share of output.

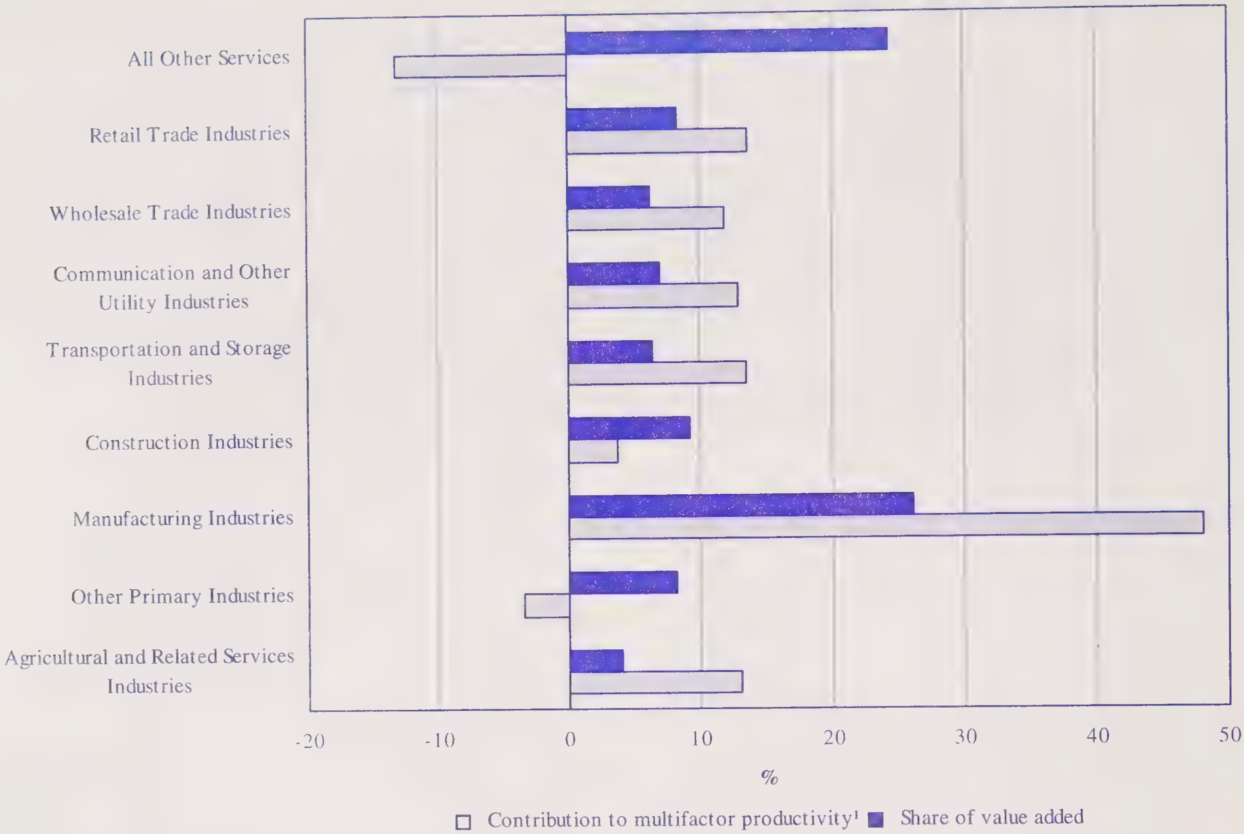
Manufacturing made the most important contribution to aggregate productivity growth over the entire period (48%), though it should be noted that it also accounts for the largest share of value added. Other high productivity growth sectors made less of an overall contribution to productivity growth simply because they are relatively smaller sectors—namely, agriculture, transportation, communications, wholesale and retail.

A better measure of the relative contribution of a sector is the percentage contribution made to aggregate productivity growth divided by the relative size of the sector. Using this measure, the most important sector was agriculture with 3.3, followed by transportation at 2.1, and wholesale, communications, and manufacturing at 1.9, 1.8, and 1.8 respectively.

1.6 Is labour productivity growth always synonymous with growth in the standard of living?

Productivity growth is generally regarded as synonymous with growth in the amount of real GDP produced per capita. Growth in real GDP per capita is often used as a measure of the standard of living.

Figure 1.6 Industry contribution to productivity growth, 1961-1995



Note: 1. Based on value-added.

However, there are periods in which movements in the growth in labour productivity (output per hour) and the growth in the standard of living (output per capita) have not been coincident. The two measures differ primarily in terms of the denominator used. The former uses hours and the latter uses population. Conceivably, productivity can increase and standards of living can fall or stagnate over periods as long as a decade if increases in jobs do not reflect growth in the population. Over the period 1961-1999, the growth in real GDP per capita has generally tracked the growth in labour productivity (Figure 1.7). However, the two measures diverged from one another in the mid-1980s and the 1990s. In particular, the growth in real GDP per capita exceeded labour productivity growth in the 1980s, but then fell back relative to the growth in labour productivity in the 1990s.

The rate of growth in Canadian real GDP per capita in the 1990s (1988-1999) was less than a third of its growth rate in the 1980s (1979-1988). Yet the productivity performance of the Canadian economy has been relatively stable over the two periods. This has posed a conundrum: how is it possible for Canada to do relatively well in one measure and poorly in the other?

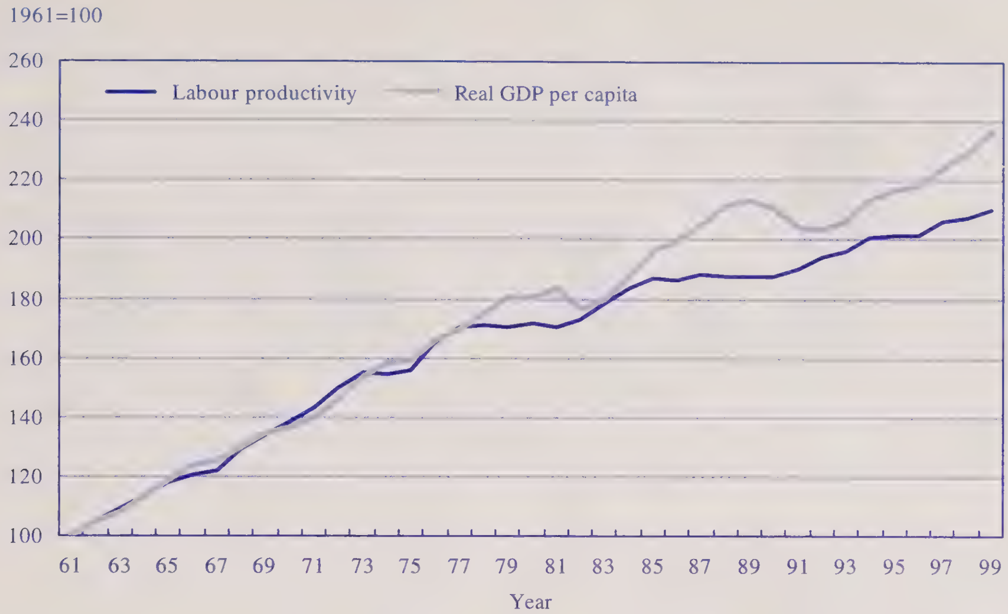
In order to explain how this can occur, it is useful to consider the inherent differences in the way the two measures are constructed.

The standard of living measure (real GDP per capita) differs in several respects from the labour productivity measure, though it is linked via an identity. By construction,

Real GDP per capita = (Real GDP/hours worked) * (hours worked/job) * (jobs/potential labour force) * (potential labour force/population) (3)

This identity means that the growth rate in real GDP per capita is just equal to the sum of the growth rates in labour productivity (the first term on the right-hand side) plus the rates of growth of the other three terms. Thus, growth in the standard of living can increase at a different rate than that of labour productivity if there are any changes in the other three terms, namely, hours worked per job, the ratio of those with a job to those who might take a job (a type of employment rate), or the ratio of the population that might take a job to the total population (a type of participation

Figure 1.7 Cumulative growth in labour productivity and real GDP per capita compared, 1961-1999



rate). The rates of growth in real GDP per capita and output per hour worked can diverge substantially during periods when the product of the employment rate, the participation rate, and the average hours worked variable is either increasing or decreasing.

Figure 1.8 indicates notable differences in the growth rates of the various components mentioned above.[8] Between the late 1980s and the mid-1990s, the growth in real GDP per capita fell while the growth in real GDP per hour worked (labour productivity) remained relatively constant. The difference between the two in each decade could have arisen from differences in any of the other components of equation (3).

In both decades, Canada experienced relatively similar increases in the percentage of the working-age population (15 and over) and relatively constant decreases in the hours worked per job. Since the rates of growth of these two variables have not changed substantially over the two decades, neither explains the decline in the growth in real GDP per capita relative to the growth in productivity.

The cause of this decline is the decrease in the number of people holding jobs relative to the population that can take jobs. While this ratio increased in the 1980s, it fell in the early 1990s. Thus, growth in real GDP per capita decreased despite the relative constancy in growth of real GDP per hour because employment growth did not keep up with population growth. This could have occurred because Canadians increasingly chose not to take jobs—for example, by taking early retirement—or because not enough new employment opportunities were created to handle the increasing population.

The Canadian experience can be examined in more detail by looking at these rates of change over a longer period going back to the late 1960s (Figure 1.9). For the sake of presentation, the terms 'jobs/age 15 and over' and 'age 15 and over/population' are replaced in Figure 1.9 with their product—the jobs-to-population ratio.

There are substantial cyclical variations in the various components. Real GDP per capita and the jobs-to-population ratio both declined substantially in the early 1980s and the early 1990s, when the Canadian economy suffered a recession. But during the mid-1980s, the jobs-to-population ratio experienced positive growth after one year of precipitous decline in 1982, thereby allowing the positive growth rates in real GDP per hour to be amplified into even higher growth rates in real GDP per capita during this period. This led real GDP per capita to increase above the long-run trend in labour productivity (Figure 1.7). However, the 1990s were quite different from the 1980s. The early 1990s experienced not just one but several years of dramatic decline in the jobs-to-population ratio, whose cumulative effect was substantial. Moreover, the subsequent growth in this ratio was weaker than in the 1980s and by 1999 was not sufficient to offset the declines of the early 1990s recession.

[8] GDP here includes both government and private sector output.

Figure 1.8 Average annual growth from peak to peak for the last two business cycles

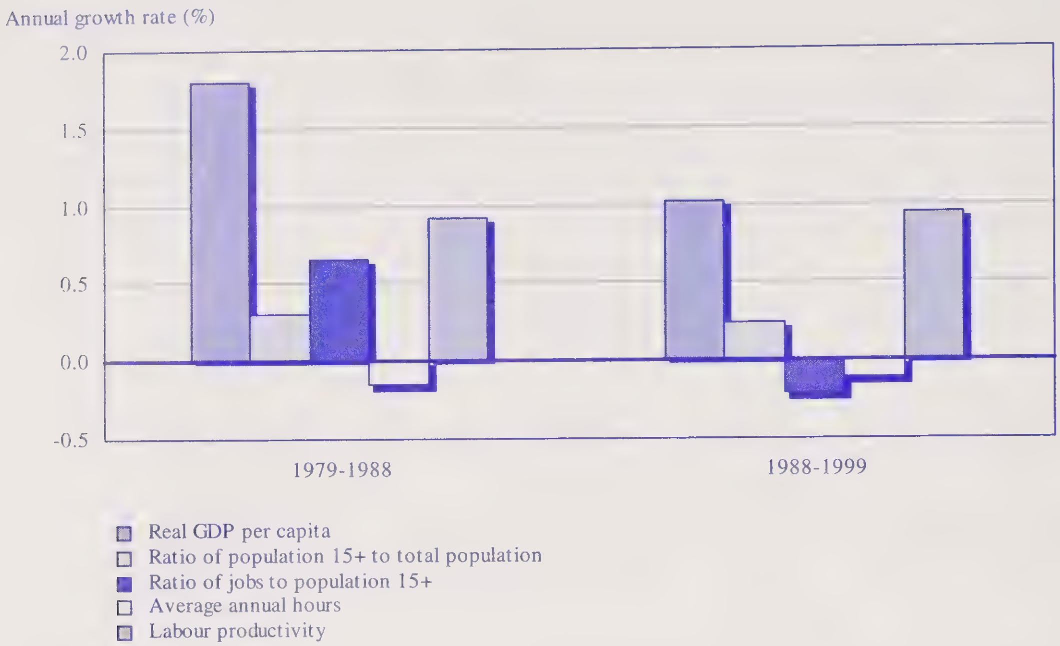


Figure 1.9 Annual growth rates in real GDP per capita, real GDP per job and jobs-to-population ratio, Canada

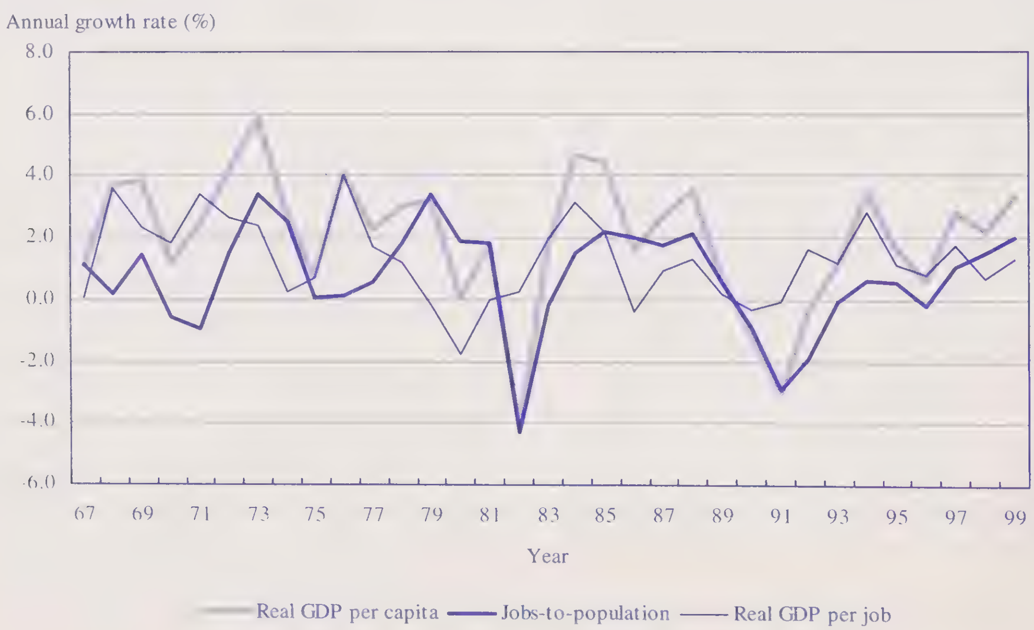
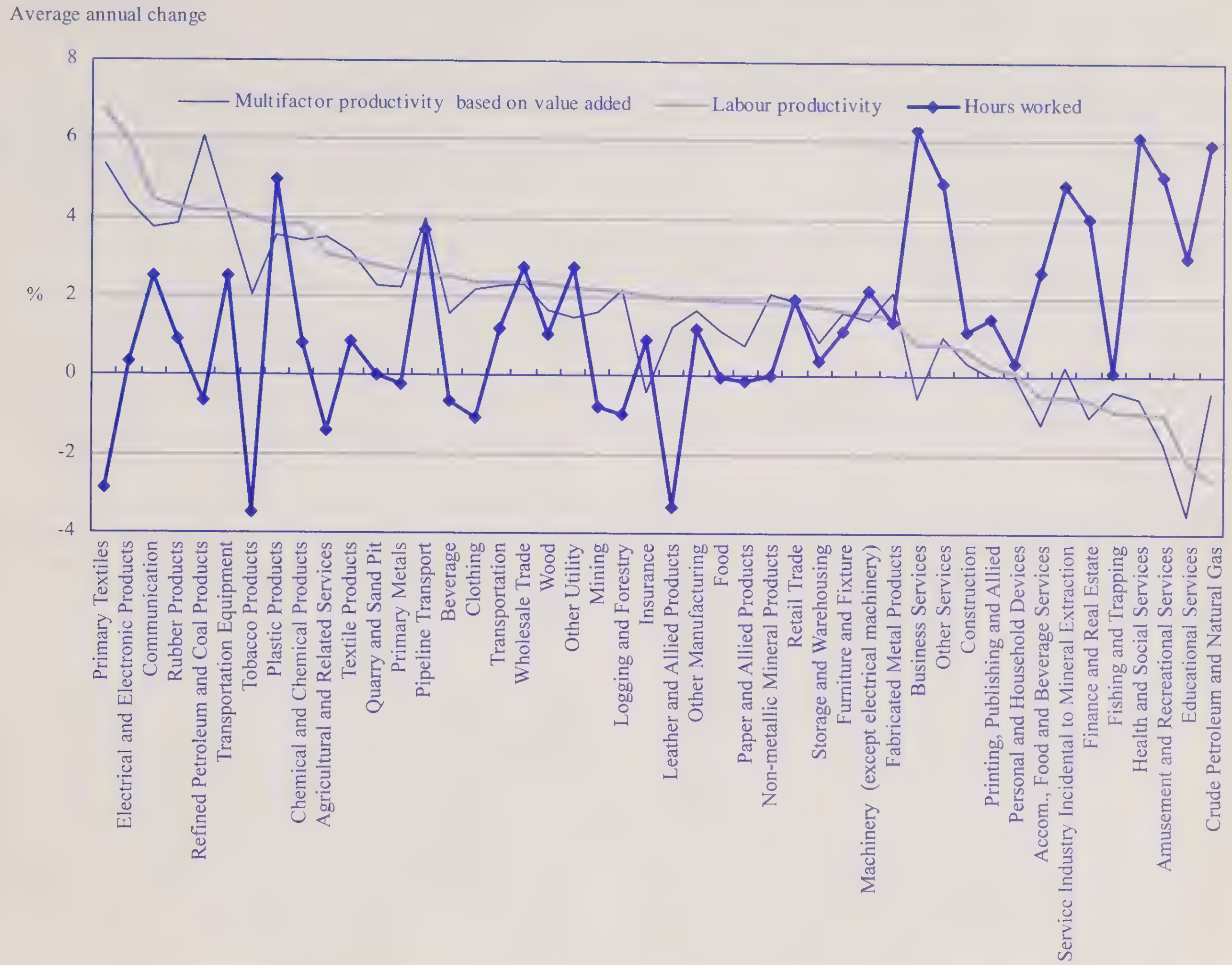


Figure 1.10 Annual rate of growth in multifactor productivity, labour productivity and hours worked by industry[1], 1961-1996



Note: 1. Ranked by labour productivity growth rates.

1.7 Employment growth and productivity

Productivity growth is sometimes seen to be at odds with a society's employment objectives. Firms that increase their productivity are seen to do so by decreasing the amount of employment required per unit of output. Whether reductions in employment requirements per unit of output also reduce overall employment depends on a number of factors.

If efficiency gains are passed on to consumers as lower prices, then output should increase. How much it increases will depend on how responsive consumer demand is to price reductions (the price elasticity of demand). If it is extremely responsive, output may increase sufficiently to offset the decrease in employment brought about by decreases in employment per unit of output. The net result could be an increase in total employment.

Perhaps more importantly, productivity gains originate in technical progress that arises from innovation—innovation that results from the introduction of new products and processes. At any point in time, this innovation affects firms that are at different points in their life cycle in different ways. Those firms that are at a more mature stage are often characterized as being involved in more process innovation, where innovation focuses on the reduction of costs by a reduction in unit labour requirements. But at the same time, new technologies are allowing the establishment of new firms. The creation of new firms leads to new jobs. In any industry then, technological change is leading some firms to create new jobs and others to reduce their employment requirements. At the industry level, the net effect of productivity gains on employment is difficult to predict.

In order to investigate the relationship between productivity growth and employment growth, the growth in multifactor productivity and labour productivity is compared to the growth in hours worked across 46 industries[9] over the period 1961-1996. Figure 1.10 plots the multifactor productivity growth rate (based on value added), the labour productivity growth rates, and the growth in hours worked. In Figure 1.10 industries are ranked from left to right by the average labour productivity growth rate. The correlation coefficient between multifactor productivity and hours worked is negative (-0.41). However, multifactor productivity is difficult to measure in some sectors such as crude petroleum and natural gas, finance and real estate, business services and amusement and recreational services. If we exclude these and examine only the top 35 industries in terms of productivity growth, the correlation drops to (-0.11). If just the manufacturing sector is examined, then the correlation approaches zero. In conclusion, when only a subsample of industries that are less affected by measurement problems is used, there is no significant relationship between multifactor productivity growth and the growth in hours worked.

If labour productivity rather than multifactor productivity growth is used and the same exercise is performed over the period 1961-1996, we find a stronger negative correlation (-0.53) between labour productivity growth and growth in hours worked at the industry level. Moreover, when we examine only the top 35 industries, the correlation in this case remains negative and significant at (-0.32). As mentioned in section 1.2, labour productivity is just the sum of multifactor productivity growth and a term that depends upon the capital/labour intensity of an industry. Since the correlation coefficient between multifactor productivity growth and growth in hours worked was lower than with labour productivity growth, this means that the stronger negative relationship between labour productivity and employment is being partly driven by increases in the capital-to-labour ratio.

In industries where labour productivity is increasing because of increases in capital per worker, employment is increasing at a slower rate, or actually decreasing. It is therefore not the measure of disembodied technological change that is being captured by the multifactor productivity measure as much as the factors that have led to a capital deepening (a substitution of capital for labour) that have had a negative impact on job growth at the industry level.

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[9] This is essentially the M-level of aggregation used in calculating productivity measures by the Productivity Group of the Micro-economic Analysis Division.

2 Restructuring and Productivity Growth in the Canadian Business Sector

JOHN R. BALDWIN, RENÉ DURAND AND JUDY HOSEIN

2.1 Introduction

This chapter examines the pattern of structural change in the Canadian economy and how it relates to productivity growth.[1] Structural change occurs when the relative importance of various sectors increases or decreases, or when the share of output produced by a given sector increases. In turn, this occurs when the sector's growth rate exceeds that of the economy as a whole.

In this chapter, we address two main issues. The first is the extent to which Canada has been shifting production away from sectors with low productivity to those with higher productivity. The second is the way in which productivity gains have brought about changes in the importance of different sectors. The first issue treats structural change as exogenous and asks only whether restructuring tends to enhance overall productivity. The second asks whether and how productivity growth influences structural change.

Aggregate productivity is just the weighted average of the productivity of individual sectors (Domar 1961). Some economies are heavily concentrated in industries that are highly productive, others in industries that are less productive. Changes that occur over time in the structure of an economy may increase the relative importance of the more productive sectors or they may do the reverse. If an economy shifts production and employment from those sectors that are less productive to those that are more productive, then aggregate productivity will increase. Explanations for lack of productivity growth are sometimes based on the notion that an economy has an inappropriate industrial structure or that structural change is not supportive of overall productivity growth. Attempts to understand the reason for growth, or the lack thereof, in aggregate productivity cannot ignore the effects of restructuring.

In turn, restructuring does not occur independently of productivity change. Productivity growth may influence the industrial structure in two different ways: directly via changes in relative prices, and indirectly via changes in relative wage rates. If differential productivity gains at the industry level are passed on to consumers via relative price changes, productivity will affect the relative demand for products at the industry level through its direct effect on relative prices. The magnitude of this effect will be determined by the relative size of the price elasticity of different markets.

Productivity growth may also influence the structure of industry demand by differentially affecting factor incomes. Productivity gains may be passed on to workers through nominal wage rate change, with some workers experiencing greater wage gains as a result of their industry's superior productivity gains. This may affect the industrial structure if the income elasticity of demand by workers in different industries is not the same and, as a result, increases in demand due to changing relative wage rates affect industry outputs differentially.

The chapter proceeds as follows: the first section examines whether structural shifts in the Canadian economy have enhanced the importance of the more productive sectors. The second section focuses on how productivity growth is reflected in relative prices, relative nominal wage rates, and relative quantities of different industries. In so doing, it investigates how productivity growth affects the structure of the economy.

[1] In this chapter, productivity estimates are based on gross output, intermediate inputs and primary (capital and labour) inputs. All indices are chained Fisher ideal indices based on annual data.

Figure 2.1 Cumulative growth in labour productivity, multifactor productivity and the real wage rate, Canadian business sector

Note 1: Based on value-added.

2.2 Measures of productivity growth in Canada

Growth in productivity can be measured using either labour productivity or multifactor productivity (MFP). Labour productivity is measured by output per hour worked and changes in labour productivity are derived from changes in output relative to changes in number of hours worked. MFP growth estimates are derived from the difference between the rate of growth of real output of the business sector and the combined rates of growth of labour inputs and other inputs used in that sector.[2]

Productivity measures are used to capture improvements in an economy's productive capability or efficiency. As such, growth in labour productivity captures the extent to which a given increase in labour inputs increases output. MFP growth measures output change relative to the changes in a larger bundle of inputs—labour and capital when value added is used as a measure of output, and labour, capital, materials and energy when gross output is used as a measure of output. Multifactor productivity growth, calculated using value added, is just the weighted sum of the growth in labour and capital productivity, where the weights are the share of labour and capital in total output (see Chapter 1).

Productivity measures are also used to measure the sources of growth. Growth in labour productivity arises either because of increases in capital intensity or because of technological change. If the objective is to measure the effect of just technological change, labour productivity measures are seen to be inferior to MFP measures because they do not capture only technological change. As pointed out in Chapter 1, the rate of growth of labour productivity is the rate of growth in multifactor productivity plus the rate of growth in the capital-to-labour ratio (the amount of capital available per hour) multiplied by the share of output going to capital. Labour productivity can then increase if the capital-to-labour ratio increases.

Measures of multifactor productivity remove the effect of changes in other measured inputs such as capital. In doing so, they provide a measure that is generally regarded as coming closer to the pure measure of technological change than growth in labour productivity measure.[3] Despite this advantage of the MFP over the labour productivity measure, the growth in labour productivity continues to be closely examined because of its relationship to changes in wage rates.

Figure 2.1 depicts the course of multifactor productivity growth, labour productivity growth,[4] and changes in the

1 Multifactor productivity can be calculated using either gross output or value added as a measure of output. In the first case, the inputs considered are labour, capital and materials. In the latter, just labour and capital. See Appendix 1 for further details.

2 Even here, the type of measure that is used in this study can be further refined to better understand the components of productivity growth. Recent work has attempted to break down simple measures of MFP and to remove from them the contribution of economies of scale and the capacity utilization (Morrison 1992). Chapter 8 contains the results of such an exercise for Canadians in manufacturing industries.

3 The measures of both MFP and labour productivity make use of the value added concept of output.

Table 2.1 Restructuring in the Canadian business sector, 1961-1995

Sector	GDP share 1961 (1)	GDP share 1995 (2)	Hours worked share 1961 (3)	Hours worked share 1995 (4)	Relative labour productivity 1961 (5)	Relative labour productivity 1995 (6)
			%			ratio
Primary Textile Industries	12.7	8.9	19.4	7.7	0.7	1.2
Manufacturing	29.4	25.3	26.0	19.3	1.1	1.3
Construction	9.3	7.0	10.2	8.5	0.9	0.8
Transportation and Communications	13.5	13.7	9.2	9.3	1.5	1.5
Wholesale and Retail	14.8	14.5	18.2	21.9	0.8	0.7
Finance, Insurance and Real Estate	10.5	13.1	3.8	6.6	2.8	2.0
Business Services	2.0	6.3	1.7	8.6	1.2	0.7
Health and Education	1.5	3.5	0.8	3.5	1.9	1.0
Other Services	6.2	7.7	10.6	14.5	0.6	0.5

Note: Columns 5 and 6 are estimated by dividing column 1 by 3 and column 2 by 4, respectively.

real wage rate in the Canadian business sector, from 1961 to the mid-1990s.[5]

Productivity growth slowed dramatically during the post-1973 period compared to the pre-1973 period. Multifactor productivity grew at approximately the same rate in the (peak-to-peak)[6] period 1988 to 1997 (0.7%) as in the earlier period from 1973 to 1979 (0.6%). However, productivity growth remains well below that posted during the period 1961 to 1973, when it averaged over 2.3% per year.

Labour productivity growth has been faster than multifactor productivity growth since the capital-to-labour ratio has generally increased over time. The growth in labour productivity, in the long run, closely mirrors the growth in real wages. Over the entire period, the annual growth rates of value added per hour worked and the real wage rate were 1.8% and 1.9%, respectively.

2.3 Patterns of restructuring

The Canadian business sector has been shifting out of goods production into services over the last 40 years (Table 2.1, columns 1 and 2). Between 1961 and 1995, the share of business sector GDP fell by 3.8 percentage points in the primary goods sector, by 4.1 percentage points in manufacturing, and by 2.3 percentage points in construction. On the other hand, the share of business sector GDP in the finance, insurance and real estate sector rose by 2.6 percentage points, and in business services by over 4 percentage points over the same period (Table 2.1).

The share of hours worked has also generally declined in the goods sector and increased in the service sector (Table 2.1, columns 3 and 4). But the decline in the share of hours worked is generally greater than the decline in the share of GDP in each of these sectors. As a result, the relative output per hour worked[7] of the goods sectors (Table 2.1, columns 5 and 6) has generally increased in the sectors that were declining in importance.

It is the relationship between these structural shifts and the productivity of these sectors that catches the attention of observers who ask whether the pattern of structural change has enhanced aggregate productivity growth.

2.4 Patterns of structural change

Structural change can improve or decrease aggregate labour productivity even when the productivity of different sectors remains constant. This is because aggregate labour productivity is the weighted average of the productivity of individual sectors.

Aggregate labour productivity (Q/L) is calculated as

$$\frac{Q}{L} = \sum_i w_i \cdot \left(\frac{q_i}{\ell_i}\right)$$

where Q is aggregate output, L is aggregate labour input, q_i is the output of sector i, and l_i is the labour input of sector i and,

[5] The real wage rate here is measured by an index of nominal wages per hour worked divided by an index of the prices of manufactured and non-manufactured gross outputs.

[6] The Canadian economy was still in its expansion phase at the end of 1997 and therefore, the estimates for 1988-1997 do not cover a full economic cycle.

[7] This is calculated as the share of GDP divided by the share of hours worked.

Table 2.2 Correlation between structural change and productivity[1]

	Change in relative industry size 1961-1995 (hours worked)	Change in relative industry size 1961-1995 (% of GDP)	Labour productivity growth 1961-1995	Multifactor productivity growth 1961-1995
	correlation coefficient			
Relative industry size (1961 share of hours worked)	-0.40		-0.002	
Relative industry size (1961 share of GDP)		-0.47	-0.003	0.07
Labour productivity growth (1961-1995)	-0.27	-0.25		
Multifactor productivity growth (1961-1995)	-0.27	-0.26		
Relative labour productivity in 1961	0.06	0.24	-0.23	0.11

Note: 1. M-level industries, except owner-occupied dwellings.

$$w_i = l_i / L$$

Changes in the share of a sector as measured by w_i will affect the aggregate labour productivity even if the labour productivity of each sector remains constant.

To understand the pattern of shifts that has taken place and its effect on productivity growth, data on structural change and productivity growth over the period 1961-1995 are examined at a level of disaggregation that has 46 industries.[8]

The relationship of growth to initial size of the sector

Initially, correlations between the structure of the economy (the relative size of the different sectors) and changes therein (changes in the relative size) are examined. Relative size is measured, on the one hand, by the share of current GDP and, on the other hand, by labour inputs as represented by the share of hours worked. Changes in relative size are measured as the percentage point changes in their share. We examine the changes in share because these variables determine whether structural shifts by themselves will contribute to changes in productivity. The sign of the correlation between size at the beginning of the period and changes in size tell us whether the largest sectors are getting larger or whether the opposite is occurring (Table 2.2).

The correlations between changes in the output share of an industry and its initial share are negative. The sectors that were initially largest have declined in importance, whereas the smaller sectors have increased in importance. Structural shifts, therefore, have evened out the distribution of both output and labour inputs over time. This indicates that the structural change that took place diversified the economy out of traditional areas.

The relationship of sectoral growth to initial labour productivity

It is also of interest to know whether restructuring has moved resources out of sectors that are relatively unproductive and into sectors that are relatively more productive. Are structural shifts concentrated in those sectors that initially had higher labour productivity? In other words, did the sectors that started off with high labour productivity expand?

It should be noted that for this exercise the level of labour productivity and not its growth rate is used. When interpreting the correlations between structural changes and this measure of industry productivity, it must be kept in mind that the measure of the level of labour productivity of an industry is influenced by the capital intensity of a sector. Sectors with higher output per hour tend to be those with higher capital-to-labour ratios and with higher wage rates. Since differences in labour productivity can be caused by differences in capital intensity as well as more fundamental disparities in productive capability or efficiency, structural change that is closely associated with levels of industry labour productivity differentials may indicate that the economy is moving resources into industries that are either more technologically advanced or more capital intensive.

To examine the relationship between structural shifts, changes in a sector's share of outputs or inputs over the period 1961 to 1995 are correlated with the relative labour productivity of a sector in 1961. The latter is measured by the ratio of the share of nominal GDP to the share of hours worked for each industry. A positive correlation between share change and initial productivity indicates that there was a general tendency for those sectors that expanded to have a higher labour productivity and for those sectors that contracted to have a lower labour productivity.

[8] See Appendix 2 for a list of the industries.

There is a weak tendency for the share of GDP in a sector to increase where initial-year labour productivity was larger. The correlation between a sector's share of GDP and its relative labour productivity in 1961 was 0.24. This indicates that the industry structure has shifted toward industries that initially exhibited higher labour productivity.

There is an even weaker positive relationship between the relative labour productivity of a sector at the beginning of the period and changes in importance of the sector as measured by its share of employment (hours worked). The correlation coefficient between these two variables was 0.06 (Table 2.2).

Restructuring has tended to slightly increase industry output and employment shares in industries that initially had a higher value added per hour worked.

The relationship of sectoral growth to productivity growth

It is also of interest to know whether those sectors that are increasing in relative size had higher productivity growth. Aggregate productivity growth is the weighted average of sectoral productivity growth. If productivity growth is higher in those sectors that are increasing in importance, this will have a beneficial impact on overall productivity growth.

The correlation between the change in the shares of GDP and MFP growth is negative (-0.26). So too is the correlation between changes in labour shares and labour productivity growth (-0.27). Thus the sectors that increased in importance had lower productivity growth.

The impact of these changes on overall productivity growth has been substantial. If the labour productivity growth of individual sectors is weighted by their 1961 labour share, average labour productivity growth over the period 1961 to 1995 is 1.85%. If it is weighted by 1995 average labour shares, it is 1.39%. The decline in the growth of average labour productivity as a result of the reweighting is about 25%.

The final question addressed is whether labour productivity growth was related to initial labour productivity levels. Is it possible that those sectors that initially had higher labour productivity were those whose labour productivity growth was fastest? Or was there a catch-up effect in that those sectors that were behind, grew most rapidly. The latter is the case, at least for growth in labour productivity, since there is a negative though not significant correlation (-0.23) between the growth in labour productivity and the initial labour productivity of a sector. On the other hand, there is a positive though not statistically significant correlation coefficient between multifactor productivity growth and the initial value of labour productivity.

In summary, restructuring had the following characteristics:

1) The sectors that were largest at the beginning of the period declined in relative importance.

2) The sectors that had higher labour productivity at the beginning of the period did not tend to increase their labour productivity most rapidly, but there was a weak tendency for them to experience faster multifactor productivity growth.

3) Overall, growth in a sector's importance was negatively correlated to growth in labour productivity and to growth in multifactor productivity, but these relationships were sufficiently weak that it is appropriate to conclude that growth in productivity was not significantly related to changes in a sector's importance.

All of this suggests that changes in a sector's importance did not respond closely to differences in sectoral productivity growth.

2.5 Productivity growth and its effect on structure

The finding that changes in industry structure are not closely related to productivity growth should not be interpreted to mean that industry differences in productivity growth had little effect on the structure of the economy. It only shows that restructuring *per se* did not contribute to our aggregate productivity growth.

This section investigates the way in which productivity growth affects key variables that in turn determine industrial structure. Productivity growth might be expected to influence both prices and wages. In competitive markets, productivity gains are passed to consumers via price changes. Industries where productivity grows relatively quickly should therefore see their prices fall faster (or grow less quickly) than industries where productivity grows less quickly. Factor inputs may be differentially affected as well. Labour may see its remuneration increase as a result of productivity improvements. In this case, differential rates of productivity across industries will be accompanied by differential rates of change in wages.

Table 2.3 Correlation between relative multifactor productivity growth and selected variables across 46 Canadian business industries, 1961-1995

	Price inverses	Nominal GDP	Hours worked	Multifactor productivity	Gross output	Relative real wages
			correlation coefficient			
Price inverses	1.00	-0.24	-0.18	0.80	0.34	0.83
Nominal GDP	-0.24	1.00	0.85	-0.11	0.82	-0.26
Hours worked	-0.18	0.85	1.00	-0.18	0.65	-0.38
Multifactor productivity	0.80	-0.11	-0.18	1.00	0.35	0.83
Real gross output	0.34	0.82	0.65	0.35	1.00	0.15
Relative real wages	0.83	-0.26	-0.38	0.83	0.15	1.00

In order to examine whether it is input or output prices that benefit from productivity growth, this section asks whether differential productivity growth is reflected in differential changes in prices and wages across industries over the period of study. It also examines the shifts in the distribution of economic activity across industries (real output and nominal output shares) and their relationship with productivity growth for 46 industries.

Productivity growth and the structure of output prices in the economy

Multifactor productivity growth affects an industry's share of output by influencing its relative output prices and quantities. Over time, an industry's relative output price changes should reflect both relative productivity differences and relative factor-price changes.

Whether output price changes fully reflect productivity changes will depend upon the level of competition in an industry. The greater the intensity of competition, the more likely it is that cost reductions that are facilitated by productivity improvements will be passed on to consumers.

Whether relative output price movements of an industry just reflect productivity change will also depend upon whether the relative prices of factor inputs, like labour, also change and how important these factor costs are to an industry. If input markets are highly competitive and factors are mobile, factor prices will tend to equate across industries. As a result, cross-industry differences in the growth in relative factor prices (such as wage costs) will be small, and inter-industry differences in productivity growth will mainly be reflected in relative output price changes.

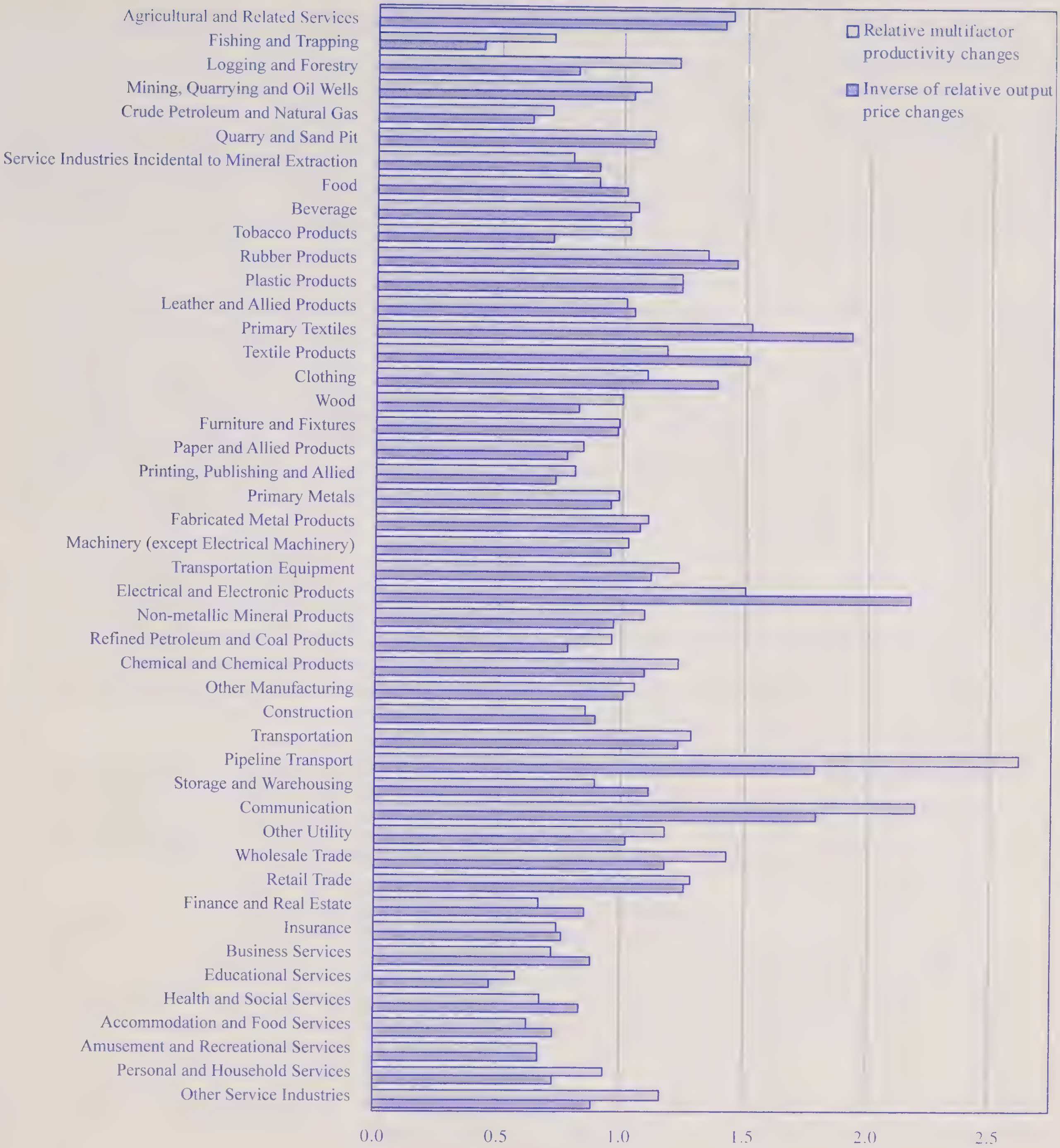
In order to investigate this relationship, the relative multifactor productivity growth is compared to the inverse of the relative output price changes of 46 industries over the 1961-1995 time period (Figure 2.2). Relative productivity growth is calculated as the productivity index of each industry divided by the aggregate productivity index. If an industry's average productivity growth over the period exceeds the average for the business sector, its relative productivity value is greater than 1; conversely, if it is below 1, then its productivity growth is less than average. Similarly price indices are normalized by dividing industries' price indices by the aggregate price index for the business sector. Since a negative correlation between price changes and productivity growth is expected, the inverse of this relative price change is then plotted in Figure 2.2 for ease of exposition.

Relative price changes and relative productivity growth are strongly related. The correlation between productivity growth and the price inverse is 0.80 (see Table 2.3). The relationship between the relative price changes and productivity growth across industries suggest that competition works to incorporate productivity changes in price changes. Industries with relatively high productivity growth rates (significantly above 1 in Figure 2.5) are also those whose output prices fall relative to the aggregate price deflator (the inverse of their relative price change is significantly above 1 in Figure 2.5). In conclusion, important productivity growth differentials across industries are reflected in changes in the general price structure over the long run.

Productivity growth and wages

Predictions about the effect of productivity growth on wage rates depend on assumptions made about the nature of competition in labour markets and the extent to which labour is mobile across industries—the extent to which workers will move from low-paying to high-paying industries in response to wage differentials and thereby equate wages paid across industries.

Figure 2.2 Relative productivity growth[1] and relative price changes across industries, 1961-1995



Note: 1.The productivity statistics used here are based on the gross output measure.

Under one set of assumptions, changes in relative wage rates will not reflect industry productivity differentials. If labour markets are competitive, inputs will be paid their marginal value product and if factors are mobile, similar workers will end up being paid the same wage across industries. Productivity growth then works to increase the overall marginal value product of labour and increase the overall wage rate that must be paid by all industries in an economy. Industries that do not sustain at least the average rate of productivity growth will have to increase prices to pay for ever-increasing wage rates or cut back on production and gradually die.

Under a second set of assumptions, wage rates might be expected to reflect productivity differentials. If workers manage to capture part of the superior productivity gains accruing to their industry via the collective bargaining process, wage rates will increase differentially to reflect differential productivity gains. If labour is not homogeneous and productivity growth is associated with differential increases in the quality of the labour force, wages might also be expected to increase in response to productivity growth.

In order to examine which of these two forces is stronger, multifactor productivity growth is correlated with nominal wage growth for 46 industries over the period 1961 to 1995. The correlation between these variables is only 0.07. There is only a weak link between changes in the nominal wage (defined as remuneration paid per hour worked) across industries and multifactor productivity growth (Figure 2.3). While average wage rates increase over time, they do not increase at a faster rate in those industries with faster rates of productivity growth. Higher productivity growth industries do not increase their wages faster than lower productivity growth industries.

While there is no close relationship between growth in relative *nominal* wages and growth in relative multifactor productivity across industries, there is nevertheless a very close relationship between growth in relative *real* wages and growth in relative multifactor productivity. Figure 2.4 plots the relative multifactor productivity changes of the 46 industries, ranked from left to right by the size of the productivity gains over the period. It also plots the inverse of the relative price changes, the changes in relative nominal wage rates, and the changes in relative real wage rates, where changes in real wage rates are derived by dividing the changes in nominal wages by the change in industry output prices.

From Figure 2.4, it is apparent that multifactor productivity growth and the inverse of price changes are much more closely related than are nominal wage rate changes. Indeed while there is considerable variance in the relative price changes, there is little variation in relative nominal wage changes. However, it is the case that relative changes in multifactor productivity growth are closely related to changes in the real wage rate with a correlation of 0.83 (Table 2.3). But this occurs because of the high correlation between multifactor productivity growth and industry price changes, not because of the correlation between multifactor productivity growth and nominal wage rate changes.

A previous section demonstrated that overall, the average real wage rate[9] grows at the same rate as labour productivity—suggesting that workers tend to be paid their relative marginal value product. That does not mean that above-average productivity gains at the industry level are translated into above-average nominal wage-rate changes. Productivity growth increases the real wage at the aggregate level but has little impact on the wage structure across industries.

In the Canadian economy, prices adjust to productivity growth differentials across industries. Real wages are modified as well through these very price changes. Very little adjustment, if any, in the distribution of the real wages occurs through adjustment in the distribution of nominal wages.

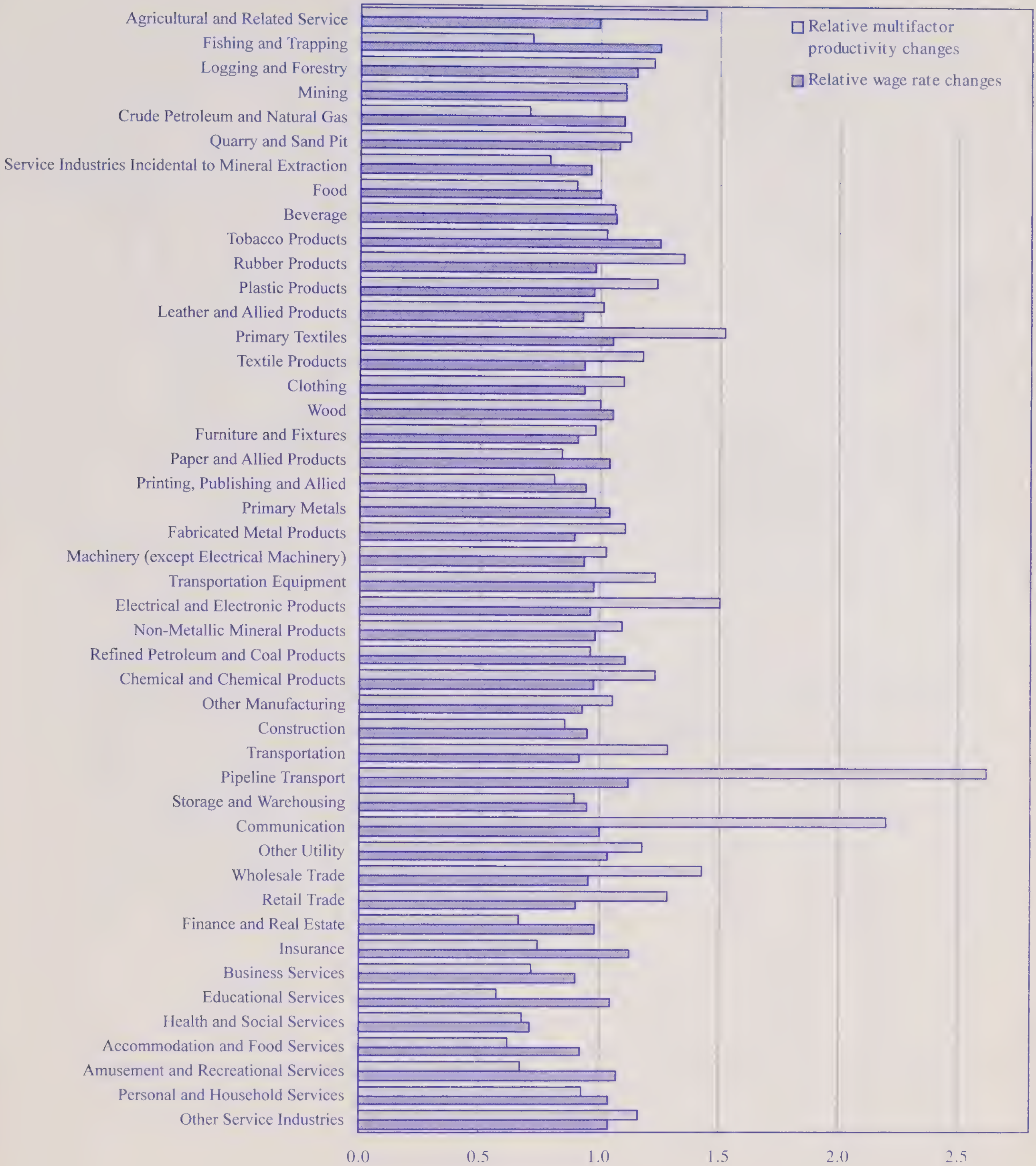
Hence, the benefits of productivity gains are largely diffused across all workers through changes in relative output prices, rather than being appropriated by the workers of the high productivity gains industries through increases in their relative nominal income.

Productivity growth and industry output shares

Changes in relative output prices, along with other factors like income that affect demand, will affect changes in relative quantities produced across industries. Relative changes in quantities will be affected by the differences in the relative prices, by variations in price elasticities, and by the extent to which changing incomes affect demand through differences in income elasticities. In turn, changes in relative prices and relative quantities will affect the relative shares of an industry or the industrial structure of the economy, since output share changes depend jointly on changes in prices and quantities. Because there are so many

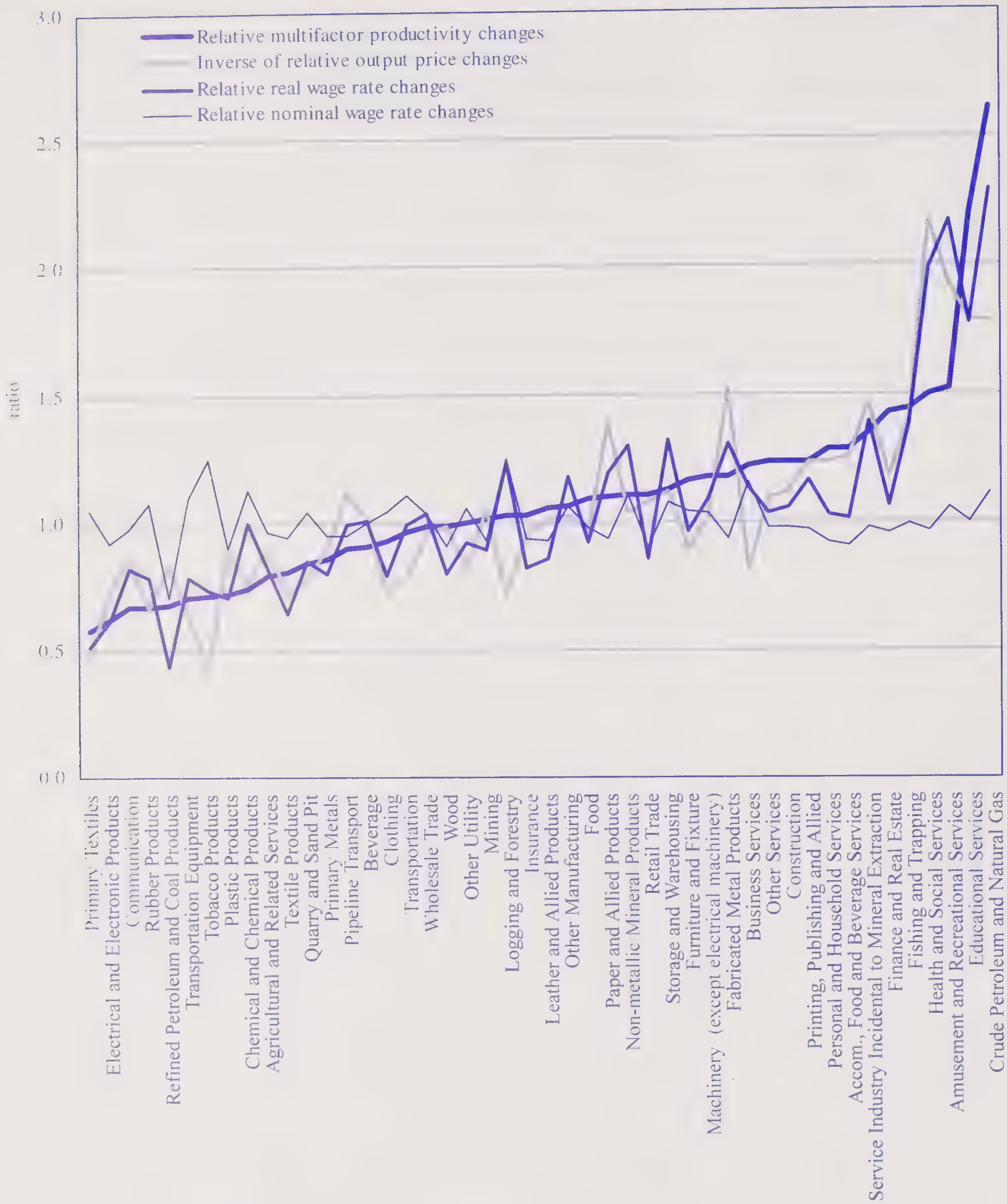
[9] Real wages, in that case, are defined by the nominal wages deflated by the aggregate price deflator rather than by each industry's output price.

Figure 2.3 Relation between relative nominal wage changes and relative productivity[1] growth across industries, 1961-1995



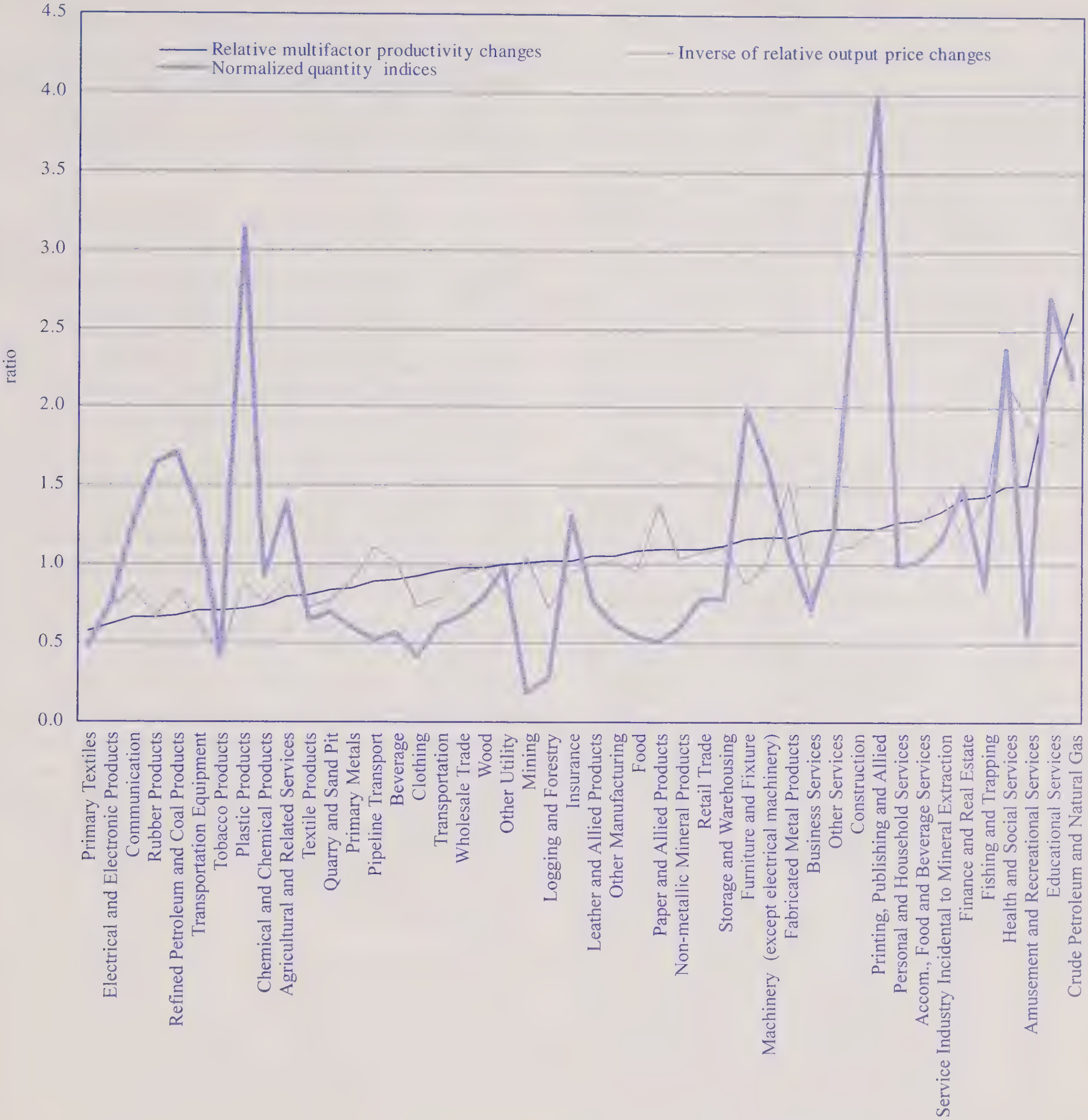
Note: 1. The productivity statistics used here are based on the gross output measure.

Figure 2.4 Relative multifactor productivity[1] growth, inverse price changes and wage rate changes, 1961-1995[2]



Notes: 1. The productivity statistics used here are based on the gross output measure.
2. Industries ranked by multifactor productivity.

Figure 2.5 Relative multifactor productivity[1] growth, inverse price changes and quantity changes, 1961-1995[2]



Notes: 1. The productivity statistics used here are based on the gross output measure.
2. Industries ranked by multifactor productivity.

factors other than price that determine demand and because price elasticities are likely to vary across industries, the relationship between multifactor productivity growth and quantity change is likely to be less than between multifactor productivity growth and price changes.

The relationship between productivity growth differentials and relative output changes across industries is depicted in Figure 2.5. While the inverse of relative price changes move closely with relative productivity, there is much less of a relationship between relative productivity growth and relative quantity growth, primarily because of the weak link between quantity change and price change. The correlation between relative quantity changes and relative price changes is -0.34 (Table 2.3). Productivity growth differentials are reflected strongly in relative price changes, but due to changing demand conditions that affect industries in quite different ways and variances in demand elasticities, relative price changes are only weakly related to relative quantity changes. The net result is that there is only a small positive correlation (0.35) between multifactor productivity growth and real gross output changes (Table 2.3).

Productivity growth differentials and shifts in nominal output share

The offsetting correlations between multifactor productivity growth and relative quantities (0.35) on the one hand and relative price changes (-0.80) on the other hand imply that productivity growth rates should not be strongly correlated with changes in industry nominal GDP. Since the correlation between multifactor productivity and price dominates, we might expect some negative correlation. This is the case since the value of that correlation was -0.11.

Despite the lack of correlation between relative multifactor productivity growth across industries and output shares, structural change has taken place. The Canadian economy has been shifting out of goods production into services over the last 40 years. Businesses, governments and households have increased their consumption of the output of the service industries over our period of study despite the relatively higher growth in the output prices of these industries. Real income growth over this period of time has shifted demand curves for services upward at a faster rate than was the case for the demand of goods-producing industries.

2.6 Summary

This chapter has demonstrated that productivity growth has affected key economic variables. Inter-industry productivity growth differentials had a substantial impact on the structure of output prices. Higher productivity growth in an industry was associated with a decline in its relative price. In turn, industries that experienced a decline in relative prices saw their relative outputs increase. However, the price effect dominates the quantity effect and multifactor productivity growth is actually negatively correlated with output share change. It is for this reason that sectors in which productivity grew most rapidly declined in terms of relative importance.

In contrast to their effect on relative prices, differential growth rates in productivity were not closely related to changes in nominal wage rates. Higher relative productivity performance at the industry level is generally not reflected in superior growth in nominal wages. The benefits of productivity growth are diffused basically through lower prices, not through higher nominal wages.

The structural shifts that have occurred in the importance of different sectors have been influenced by productivity growth. The shifts that have occurred from high-productivity to low-productivity industries that were the result of changing consumer demand have no doubt been attenuated by the effect of productivity growth on relative prices. Income elasticities or changing tastes led consumers to substitute demand away from goods to services over this period. The fact that prices fell in the goods sector relative to the services sector because of differential productivity growth rates would have attenuated the shift that was otherwise occurring. Rising income has tilted demand away from the consumption of manufactured goods to services, despite their declining relative prices brought about by higher productivity growth.

2.7 Conclusion

Canadian long-run productivity growth has followed a path that is similar to the one registered in many other industrialized countries. The strong productivity growth of the 1960s and early 1970s was followed by sluggish growth thereafter. The slowdown in productivity growth was accompanied by a slowdown in output growth.

The slowdown in productivity growth is sometimes seen to be related to structural shifts in the economy that have moved resources away from high productivity goods-producing industries to lower productivity services-producing industries. At first glance, changes in industrial structure away from high productivity industries appear to suggest that the Canadian economy did not react in a fashion that was conducive to productivity growth—that the industrial environment was not supportive of growth. It is all too

easy to suggest from this that the Canadian economy did not respond to productivity growth. This is incorrect.

The question as to whether the structure of the Canadian economy helped or hindered productivity growth contains the implicit notion that a dynamic economy is one where the most productive sectors are growing in importance. It is sometimes assumed that rapid productivity growth should increase the size of a sector. This assumption is wrong for two reasons.

First, there is no reason to expect the sectors with the highest productivity growth would increase their share of total employment. Productivity growth may mean lower employment per unit of output and unless output is increased very substantially, those industries that experience the most rapid productivity growth will not increase their share of employment. In research that uses microeconomic data on plant performance, we find that plants that increase their market share also increase their labour productivity more than their compatriots but do not increase their employment share (Baldwin, Diverty and Sabourin 1995). This chapter has shown that the same is true of industries. The industries that increased their labour productivity growth the most did not increase their share of employment.

Second, there is no reason to expect that the output share of sectors that have the highest productivity growth should increase. If productivity gains are passed on to consumers, the sectors that have higher productivity gains should have greater price declines. While quantity should increase in response to price declines, there is no reason to expect that it will do so sufficiently to completely offset the price declines. This means that the relative GDP share of sectors with productivity increases may fall. In turn, this means we should sometimes expect to find a negative correlation between productivity growth and changes in GDP shares. This is what happened in Canada during the period 1961 to 1995.

This chapter has demonstrated that industry differences in productivity are not felt so much in changes in the importance of a sector as measured by GDP as in the changes in the relative prices of different sectors. Those who are seeking evidence of the effect of differences in relative productivity on the economy would be advised to seek them first in changes in relative prices and not to presume that since productivity growth and structural change are only weakly linked, this can be seen as evidence of maladjustment in the economy.

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3 The Precision of Productivity Measures

JOHN R. BALDWIN AND TAREK M. HARCHAOUI

3.1 Introduction

Statistics Canada is constantly improving its productivity measures so as to provide reliable information to the public. Nevertheless, uncertainty is clearly present in any statistical exercise. For the purposes of exposition, point estimates of productivity normally are the focus of attention. But the statistical process can rarely say with 100% certainty that statistics like productivity growth (or the unemployment rate) take on a particular value. Rather, point estimates need to be supplemented with confidence intervals within which the real values can be said to lie. Users require information on the size of these intervals if they are to make informed judgements on the use of the statistical product.

In order to fulfill this requirement, this chapter has three related goals. The first is to identify the size of the bounds that should be placed around the point estimates of productivity growth. The second is to evaluate the extent to which these bounds affect the use of productivity measures. The third is to draw implications about how these bounds affect cross-country comparisons of productivity performance.

Productivity measures are derived from data on the rates of growth of outputs and inputs. All the data that are used in producing estimates of productivity growth are subject to uncertainty—what we shall refer to as 'measurement error', which may be due to uncertainties resulting from the use of statistical sampling, inappropriate measurement techniques or data—capture problems.

Sampling may affect estimates of output and inputs used by the productivity program. These estimates are derived from surveys that use a complex stratified random sample taken from the whole population of households and corporations.[1] As such, these estimates are subject to sampling error that can be estimated.

Non-sampling errors from a number of sources may also affect these estimates. For instance, respondents to the survey may not have fully understood the questionnaire; there may have been data capture problems; or the use of imputation methods may have introduced additional uncertainty.

Various methods are used to reduce errors of these types in surveys. For example, Statistics Canada attempts to minimize respondent confusion with extensive pilot tests of surveys. Methodological advances are constantly being made in imputation techniques. Quality control techniques are used to monitor data capture. Nevertheless, it must be recognized that most data are subject to error and should be used with a clear understanding of the sources and extent of measurement error.

Statistics Canada provides data users with information on the nature of the errors and, where possible, quantitative indicators on the quality of the data. In the case of surveys like the Labour Force Survey (LFS), for example, measures of the coefficient of variation (CV) are available. A CV—the ratio of the standard error of the estimate to the mean—can be used to provide a quick measure of the interval within which the true but unobserved estimate of the mean falls.

Quantitative indicators of uncertainty, such as those available from the LFS do not extend to all the primary sources of data that are used by the productivity program. In fact, many of the data series originating from the National Accounts and elsewhere do not have CVs attached to them—yet they are all subject to a certain amount of imprecision.

[1] For example, Labour Force Survey for labour, Capital Expenditures Survey for investment, and Annual Survey of Manufactures for shipments.

Some of the uncertainty inherent in these statistics may be due to non-sampling errors that arise in data processing, or in the techniques that are used to construct time series estimates. For instance, the capital stock data are compiled from an investment survey, and the CVs from this survey are available. However, the capital stock program transforms the investment data into capital stock data by aggregating current investments to provide estimates of capital stock in the economy. These data manipulation techniques tend to introduce additional types of imprecision into the capital stock estimates since they involve assumptions about the length of life of capital and how rapidly capital wears out (the shape of the depreciation function). In some situations, these assessments are based on observed data, whereas in others, assumptions are based on expert judgement.

The capital stock program is not the only area where data transformation introduces measurement errors. As outlined in Appendix 1, the productivity program also transforms several data series. For instance, the labour component of the program relies heavily on the LFS for employment data. However, supplementary data are also used in an effort to improve the accuracy of the labour estimates for certain industries. This requires a certain amount of assumption and data editing, which introduces additional imprecision into the final productivity estimates.

The productivity program also uses expert judgement to produce a coherent set of adjustments to the data that, in their raw form, are not ideal for estimating productivity measures. For example, adjustments are made to the LFS data to account for strike activity and holidays. Despite the care exercised in adjusting the data that are used to derive productivity measures, errors remain in the data series.

It is important to give data users some idea of the bounds that should be used around point estimates of productivity growth. Those who wish to use the productivity estimates to conduct international comparisons need to have an understanding of the precision of the productivity measures. For example, between 1961 and 1997 multifactor productivity growth in Canada and the United States was 1.2% and 1.0%, respectively. Are these differences meaningful in a statistical sense? Are they statistically significant? An estimate of the bounds that should be placed around the point estimates or the variance of the estimates is required before questions of this type can be answered.

3.2 Error evaluation

In this chapter, we evaluate the precision of productivity estimates in several ways:

- using classical estimation techniques to estimate confidence intervals;
- examining what happens to estimates when we change the methodology for one of the most important inputs (for example, capital stock);
- asking whether international comparisons that use imperfect measures of inputs are imprecise; and
- asking how revisions in data affect productivity estimates.

Each method produces different confidence intervals or boundaries that should be employed when using productivity point estimates. In each of the following sections, we indicate the boundaries that are applicable in different circumstances.

Confidence intervals

A confidence interval provides bounds within which we would normally expect the true value of the estimated statistic to lie. For example, 19 times out of 20, a 95% confidence interval for a productivity growth rate will cover the true growth rate.

In estimating classical confidence intervals for our productivity estimates, we will make use of parametric as opposed to non-parametric estimation techniques of multifactor productivity.

The standard non-parametric (or accounting) technique calculates productivity as the difference between the rate of growth of output and the weighted average of the growth of inputs. The weights are simply the shares of factor compensation, which are estimates of marginal revenue products of different inputs.

Table 3.1. Parametric multifactor productivity growth estimates of Canadian manufacturing industries, 1961-1995[1]

	Parametric	Parametric lower bound[2]	Parametric upper bound[2]
	average annual growth rate %		
Food and Beverages	0.31	0.26	0.36
Tobacco	0.61	0.46	0.76
Textile	1.36	1.15	1.57
Clothing	0.85	0.67	1.03
Wood and Lumber	0.79	0.59	0.99
Furniture and Fixture	0.51	0.40	0.62
Paper	0.13	0.10	0.16
Printing and Publishing	0.01	0.01	0.01
Chemical	1.13	0.96	1.30
Refineries	0.51	0.40	0.62
Rubber	1.09	0.83	1.35
Leather	0.63	0.52	0.74
Non-mineral	0.84	0.74	0.94
Primary Metal	0.52	0.39	0.65
Fabricated Metal	0.86	0.74	0.98
Machinery	1.33	1.15	1.51
Electrical and Electronic	1.36	1.10	1.62
Transportation Equipment	1.17	0.97	1.37
Total Manufacturing	0.78	0.64	0.92

Note: 1. Based on gross output.
Note: 2. 95% confidence intervals.
Source: Chapter 8 of this publication.

These estimates of the standard non-parametric technique are essentially equivalent to those that would be produced using a parametric technique and assuming a production function of a specific type, that there are constant returns to scale, perfect competition and full capacity. We use this technique, which also readily produces confidence intervals of estimated parameters, to examine the size of the bounds that must be applied to estimates of multifactor productivity. For our purposes, we use a cost function rather than a production function (see Chapter 8)[2] to construct confidence intervals for assessing the precision of productivity estimates.

The parametric multifactor productivity estimates and their confidence intervals are presented in Table 3.1 for the entire manufacturing sector and for individual industries. The 95% confidence interval for the parametric estimate of the manufacturing sector extends about 0.28 percentage points, from 0.64 to 0.92. Alternately, the confidence interval is 0.14 percentage points above and below the point estimate of 0.78.

The confidence intervals that should be applied to subsectors are slightly larger. They range up to 0.50 percentage points and average about 38% of the mean point estimate.

The effect of alternative assumptions of inputs

Estimation of capital stock

We can also provide bounds around the productivity estimates by investigating how the estimates change when alternative methodologies are used to construct the input or output series that are used to calculate productivity growth.

To illustrate this technique, we will examine alternative methods that can be used to measure capital stock, each of which is quite reasonable. This is not a case where one methodology is definitively better than another. Rather, no consensus has emerged among economists on the best method.

We provide a different set of bounds for productivity growth rates by estimating productivity with alternative assumptions of capital stock. This allows users to assess how alternative methodologies for estimating capital stock affect the point estimates of productivity growth. It is particularly useful in cross-country comparisons when different countries use different techniques to estimate capital stock.

Capital stock is calculated in both Canada and the United States by the perpetual inventory technique. The declining balance method cumulates annual estimates of investment over time into an estimate of the capital stock, as follows:

$$K_t = I_t + (1-\delta)K_{t-1} \qquad (1)$$

where K_t is real net capital stock, I_t is real investment, δ is the depreciation rate, and t refers to the year.

By successive backward substitution for K_{t-1} in (1), we can relate K_t directly to the initial value for the capital stock, K_0. Hence, K_t becomes a weighted sum of all past levels of investment and the depreciated value of the initial real capital stock.

$$K_t = \sum_{i=0}^{t-1}(1-\delta)^i I_{t-i} + (1-\delta)^t K_0 \qquad (2)$$

[2] Chapter 8 shows the differences between the production and cost function approaches to measuring productivity and how they can be used to measure productivity performance.

Figure 3.1 Survival rates for investments

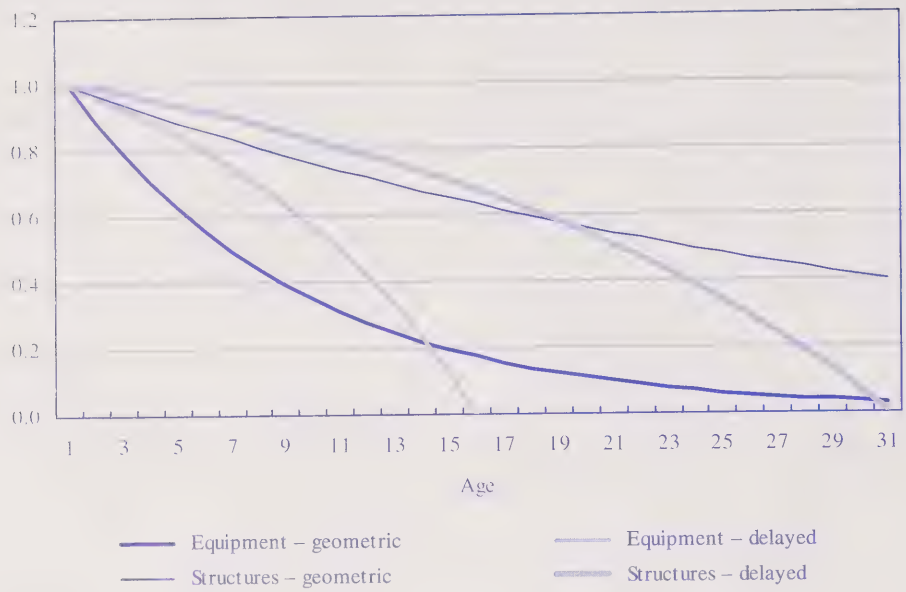
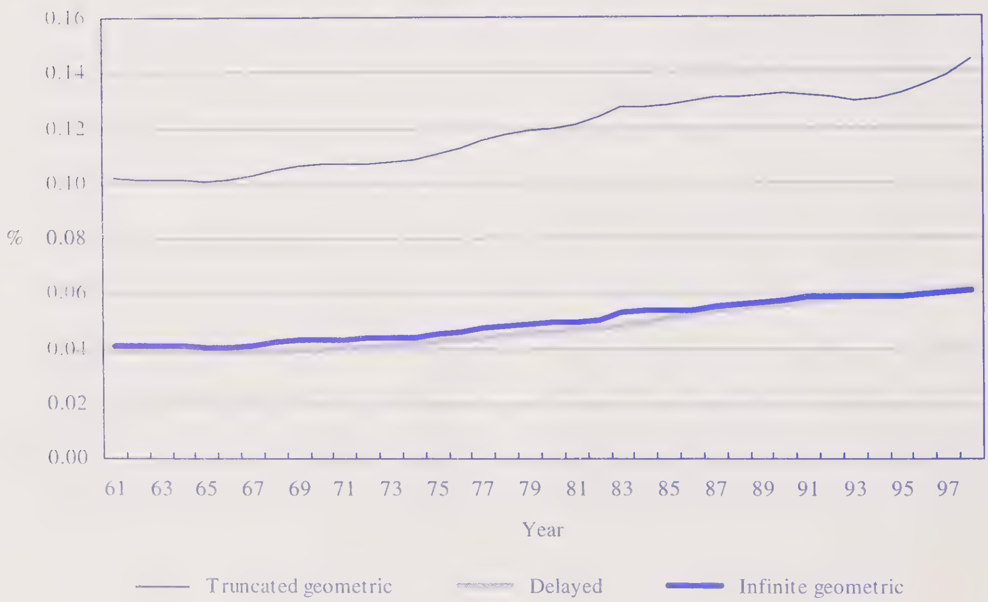


Figure 3.2 Depreciation rates of capital stock compared, business sector, 1961-1998



Measurement error may be introduced into the capital stock series through any of the three components of (2): the I_t series, K_0, and the depreciation profile that generates δ.

The error associated with the shape of the depreciation function arises because the choice of the shape is often subject to a certain degree of arbitrariness. For example, in the United States, the U.S. Bureau of Economic Analysis (BEA) and the U.S. Bureau of Labor Statistics (BLS) both produce estimates of capital stock, but they use different assumptions about the shape of the efficiency pattern of an asset.[3] The BEA assumes that the efficiency pattern follows a geometric distribution, whereas the BLS assumes a hyperbolic distribution.

The geometric distribution assumes that the rate of depreciation is a constant. The function that represents the value of $1 of original investment at age x is

$$F(x,L) = \delta(1-\delta)^{(x-1)} \tag{3}$$

In the case of the BEA, $\delta = \frac{R}{L}$, where R is an arbitrary constant and L is the life assumed. Thus,

$$F(x,L) = \frac{R}{L}\left(1-\frac{R}{L}\right)^{(x-1)} \tag{4}$$

The BEA uses the following approximation values for R: $R = 1.65$ for equipment and $R = 0.9$ for structures. L is taken from a table of lives that are obtained from a variety of sources (Fraumeni 1997, p. 9).

With a geometric efficiency pattern, the value of an investment declines at a constant rate δ, and the expected length of life yielded by the geometric distribution is $\frac{1}{\delta}$ or $\frac{L}{R}$. This means that the expected length of life of a structure whose L is taken as 30 years is 33 years. The expected length of life of equipment such as automobiles whose L is taken as 9 years is 5.5 years.

The delayed hyperbolic density function for an investment of life L is given by,

$$F(x,L) = \frac{[L-(x-1)]}{[L-\beta(x-1)]} - \frac{(L-x)}{(L-\beta x)} \tag{5}$$

where the BLS assumes $\beta = 0.75$ for structures and $\beta = 0.5$ for machinery and equipment.

Differences in the profile of the value of an investment of $1 for the two different assumptions about the efficiency and depreciation shapes are depicted in Figure 3.1. The geometric distribution for machinery and equipment assumes a life of 15 years, which along with the BEA assumption that $R = 1.65$ gives an annual rate of depreciation of 11%. For structures, we have chosen a length of life of 30 years, which along with the BEA assumption that $R = 0.95$ gives an annual rate of depreciation of 3%. The hyperbolic survival curve has been calculated with the assumption that $\beta = 0.75$ for structures and $\beta = 0.5$ for machinery and equipment.

The remaining or net value of an investment follows quite different paths for the geometric and the hyperbolic functional forms. Yet there are legitimate differences of opinion about which formula should be employed, as evidenced by the fact that the BEA uses one formula and the BLS uses another. Therefore, one yardstick that can be used to evaluate the precision of productivity measures is the difference in the productivity estimates that arise from the use of the two different capital stock estimates.

Sensitivity of productivity estimates to alternative assumptions on capital stock

To develop this yardstick, the productivity growth rate is calculated using alternative measures of the Fisher index of capital input[4]—where capital is calculated using the geometric and the delayed function outlined above. We also employ a variant of the geometric method, referred to here as the truncated geometric, that has long been produced by the Investment and Capital Stock Division of Statistics Canada (ICSD). In the case of this latter method, depreciation is assumed to follow a geometric pattern, but the function is truncated at the expected length of life of capital so that total depreciation at this point equals the original value of the asset (Statistics Canada 1994).

[3] An efficiency pattern is a pattern describing the productive services derived from an asset as it ages. The efficiency of a new asset is typically normalized to 1.0. As an asset declines in efficiency, its efficiency has a value of less than 1. There is a direct correspondence between efficiency patterns and depreciation patterns. Present and future declines in efficiency result in depreciation or declines in the value of an asset as it ages.

[4] See Appendix 1 for the method used to obtain a Fisher index of the growth in capital input.

Figure 3.3 Fisher index of capital inputs, business sector, 1961-1996

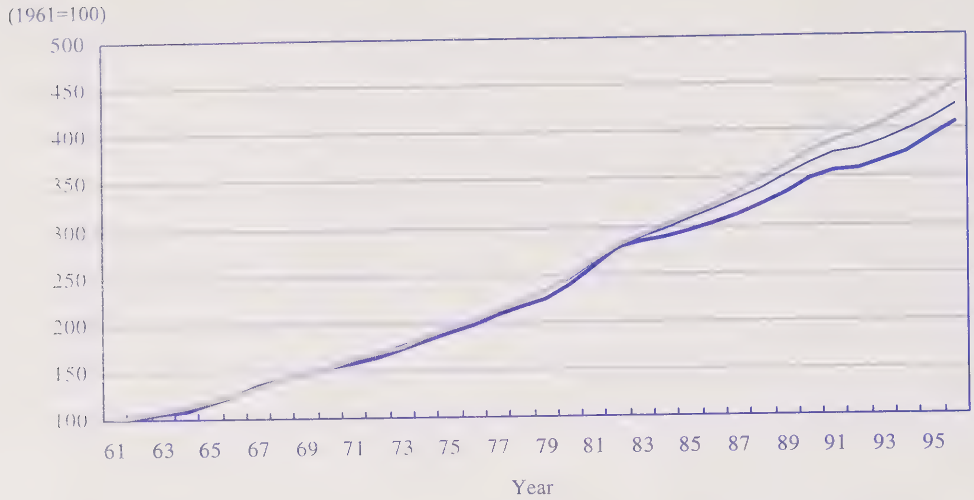


Figure 3.4 Capital inputs, business sector, average annual rates of growth, selected periods

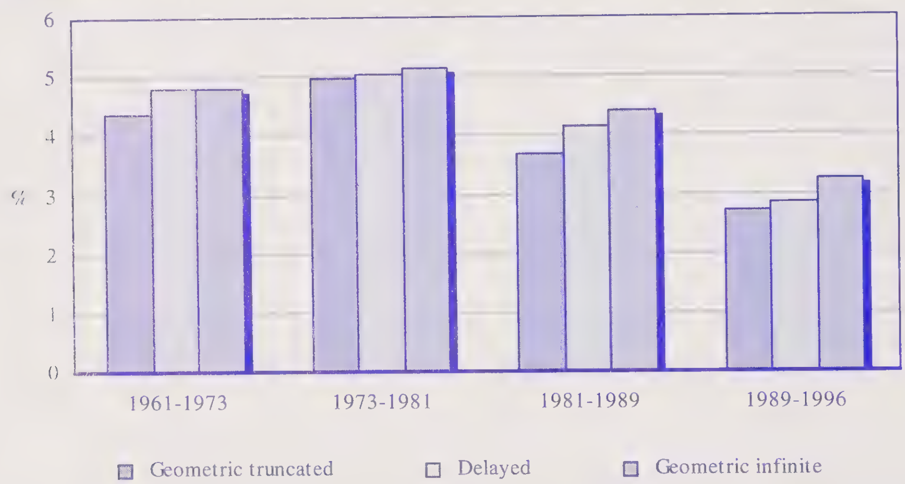


Figure 3.5 Cumulative growth in multifactor productivity[1] using different measures of capital stock, business sector

Note 1: Based on value-added.

These three different assumptions of the rate of depreciation of capital yield quite different estimates of the overall capital input. In Figure 3.2, we plot the rate of depreciation for each method over the period 1961-1998. This rate is obtained by dividing the value of the annual depreciation of capital stock by net capital stocks produced by ICSD. The truncated geometric yields the highest average depreciation rate (11.9%), followed by the geometric (5.0%) and the delayed hyperbolic functions (4.8%).

While the difference in depreciation rates between the truncated geometric method and the other two is large, it translates into much smaller differences in the rate of growth of capital input. Figure 3.3 displays the index of capital input for the period 1961-1996. Figure 3.4 shows its average annual growth rate for various subperiods. Over the entire period, the geometric grew the fastest at 4.4% annually, and the truncated geometric grew the least at 4.1% per year. The hyperbolic delayed growth rate fell between the other two, with an annualized growth rate of 4.2%.

The impact of these different capital input estimates on the productivity growth rate is provided in Figure 3.5. The technique that produced the slowest rate of growth of capital input had the highest growth rate in multifactor productivity (1.16%) over the period 1961-1996. The technique that yielded the highest rate of growth of capital input—the non-truncated infinite geometric—yielded an annual growth rate of 0.96%—a difference of 0.20 percentage points over the same period.

Clearly then, alternative assumptions about the form of the depreciation function that is used to construct capital stock have an impact on the estimate of multifactor productivity—one-fifth of a percentage point over a 36-year period. The average of the three growth rates is 1.05%, and the range (0.20 percentage point) divided by the average is 18%.

International comparisons and multifactor productivity estimates

In the first two examples, we have shown the type of bounds that should be placed around productivity estimates as a result of unavoidable sampling error or because of legitimate differences of opinion with regard to estimation techniques for inputs.

A third type of problem arises when incorrect data are used to estimate productivity. When an imperfect measure is used, the productivity estimates may be biased. To illustrate this problem, we turn to estimates of labour inputs.

Canada and the United States both utilize hours worked as a measure of labour input. However, international comparisons by the OECD use employment, measured by the number of jobs, primarily because they are interested in comparing countries, not all of which collect hours worked. The number of workers employed is commonly used in many studies that compare a large number of countries.

Hours worked is a better measure of the labour input into the production process when non-standard workweeks are important in an economy and if their importance has been changing over time. If increases in hours worked and employment over time are not the same, making use of employment rather than hours worked can provide misleading results about the rate of growth of labour inputs and, therefore, about the rate of productivity growth.

In Canada, hours worked and numbers employed (numbers of jobs) have not been increasing at the same rate. Figure 3.6 shows the cumulative rate of growth of both hours and employment over the period 1961-1996. Over this period, hours and employment grew at an average annual growth rate of 1.80% and 2.05%, respectively. The number of workers who work non-standard hours has increased over the last 20 years and, as a result, the true labour input (hours worked) has increased at a slower rate than employment.

We can evaluate how much of an effect this has on our estimates by recalculating the measure of multifactor productivity with employment rather than hours worked for the period 1961-1996 (Figure 3.7). Over this period, multifactor productivity using hours increased by 1.17% a year as compared with 1.0% if employment had been used in the estimates of labour input.

Thus, international comparisons made with data on employment will bias downwards the estimate of Canadian multifactor productivity growth. If these studies bias the estimates of all countries in the same direction, they may still provide a reasonably accurate ranking of Canada's relative position. But they will bias Canadian performance downward relative to that of other countries where rigid labour markets result in less flexibility for workers and cause hours worked and employment to increase at more or less the same rate.

Revisions and the accuracy of productivity estimates

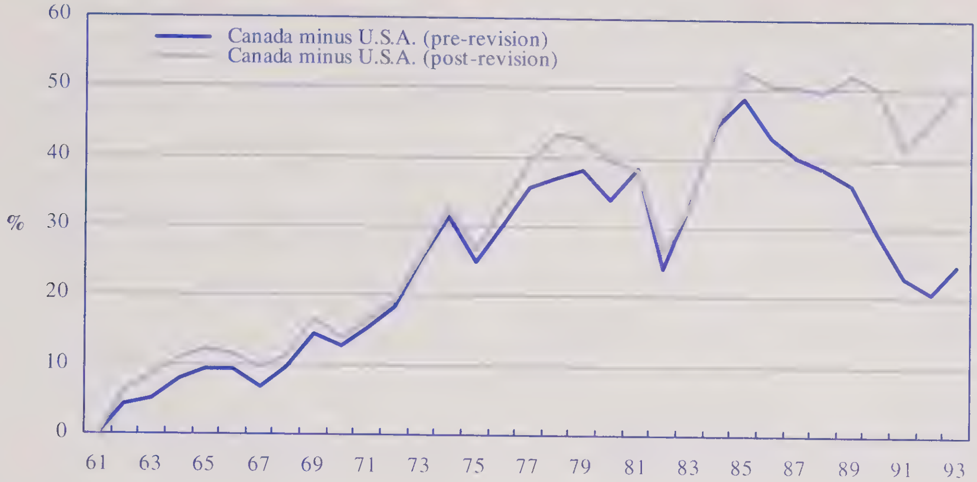
Another method of evaluating the size of the bounds that should be placed around more recent productivity estimates is to examine the size of revisions that are made to the

Figure 3.6 Fisher index of employment and hours

Figure 3.7 Cumulative growth in multifactor productivity estimates[1] under alternate labour input concepts, 1961-1996

Note 1: Based on value-added.

Figure 3.8 Cumulative differences in multifactor productivity growth[1] for Canada and the U.S., manufacturing, 1961-1993



Note 1: Based on value-added.

productivity estimates. Revisions to estimates are different from measurement errors due to sampling design problems or inappropriate measurement techniques described above.

Productivity measures are meant to provide estimates of technical progress. Trends in measures of technical progress only emerge over longer periods. Short-run or annual productivity estimates provide information that is less useful for this purpose.

Short-run annual estimates are less accurate measures of technical progress for two reasons. First, they are affected by short-run changes in capacity utilization that sometimes mean short-run changes hide long-run trends. Second, the most current annual measures are less accurate because they are based on preliminary data that are subject to revision. The size of the revisions that have occurred in the past serve as guides to the size of the confidence intervals that should be placed around preliminary point estimates of productivity growth.

For example, multifactor productivity measures in the short run are influenced by the fact that capacity utilization changes over the cycle. In recessions, installed capacity is not used to its fullest and estimates of capital services that do not take this fact into account will overstate the amount of capital being used. While there are statistical methods that can make corrections for this problem, their robustness and accuracy have not been fully established. As a result, short-run multifactor productivity estimates probably incorporate more of these short-run capacity fluctuations than is ideal.

This problem can be overcome only if long-run averages of productivity growth that cover an entire business cycle are taken. However, many users of productivity data cannot wait until an entire business cycle is completed. They need estimates of productivity annually. For that reason, Statistics Canada produces annual estimates throughout the business cycle, but it is only realistic to recognize that they are subject to revisions because of the addition of new information on components of GDP and to changes arising from periodic rebasing that takes into account changes in the structure of the economy (Jackson 1996).

The modifications that were made in 1998 to the Canadian and U.S. multifactor productivity estimates in the manufacturing sector illustrate the effect of revisions on productivity estimates.

Prior to the most recent historical revisions of the National Accounts Statistics Canada reported that the cumulative multifactor productivity growth in the manufacturing sector was 4.4% for the period 1987-1996. After the revision, the cumulative increase in productivity rose to 9.1%, in effect doubling the estimate of productivity growth since the last rebasing year (1986). It had less of an effect on the long-run rate of growth between 1961 and 1996, which increased from an annual average of 2.1% before the revision to 2.3% afterwards. This was an increase of about 8% in the rate of growth.

Changes as a result of revisions are not unique to Statistics Canada. In 1999, the BLS produced productivity estimates for the U.S. manufacturing sector that were not only

benchmarked to the 1992 input-output tables but also reflected the revisions to the capital stock estimates made by the BEA (U.S. Bureau of Labor Statistics 1999, pp. 8-10). This revision reduced the U.S. manufacturing productivity estimates substantially, from a cumulative index of 151.2 to 139.9 in 1993, taken to a base of 1961=100. This is equivalent to an annual reduction from 1.30% to 1.06% over the same period, or a reduction of 0.245 percentage points. Over the period 1985 to 1993, the revision reduced annual growth from 1.04% to 0.78%, or 0.26 percentage points.

If we add the upward revision of about 0.15 percentage points in the Canadian estimates over the early 1990s to the downward revision of about 0.26 percentage points in U.S. estimates, we have a range of about 0.41 percentage points that we should apply before we treat short-run differences between Canada and the United States as being meaningful.

Revisions such as those described can dramatically affect cross-country comparisons. In Figure 3.8, we report the difference in the cumulative growth rates of Canada and the United States for the manufacturing sector between 1961 and 1993 before and after the revisions. Each series is the difference between the cumulative growth index based to 1961=100 for Canada and the United States. For example, in 1993 the unrevised cumulative index was 176 for Canada and 151 for the United States—a difference of 25 points.

Revisions made by both countries to their national accounts affect the nature of intercountry differences. The 1999 revisions substantially changed the cumulative difference of productivity growth as of 1993—doubling it from approximately 25 to 50 percentage points. More importantly, an entirely different picture of the relative performance of the two countries emerged in the early 1990s. Before the revisions, Canada appeared to have fallen relative to the United States. After the revisions, the two countries moved more or less in pace with one another.

Incorporating more current estimates of the structure of the economy into the productivity measures can therefore lead to large revisions in short-run productivity estimates. Users of productivity estimates that cover the very recent past should be aware that revisions can have a substantial impact on short-run productivity estimates.

3.3 Conclusion

Productivity growth is measured as a residual. It is the growth of output that we cannot explain by input growth. It is what we do not know about the growth process.

When the estimates of productivity growth that are produced by Statistics Canada are used for analysis, it should be remembered that there is a confidence interval that should be drawn around these estimates when drawing inferences about the true rate of productivity growth.

Like unemployment estimates, productivity estimates are subject to measurement error. However, the unemployment estimates, which are derived from stratified random samples of populations, can make use of classical statistical sampling theory to generate estimates of confidence limits. It is more difficult to specify the size of these limits for productivity estimates because of the way in which the productivity statistics are generated.

In this chapter, we have suggested several approaches that can be used to gauge the intervals that should be attached to productivity estimates.

First, using classical statistical techniques and the assumption that there is no error in the estimates of inputs yields a confidence interval of around 0.3 percentage points. Second, changes in assumptions about the way in which capital estimates are calculated yield an estimate of the interval of between 0.2 and 0.3 percentage points. This suggests that the minimum confidence interval around the multifactor productivity estimates should be 0.3 percentage points. Since these two errors may be partially additive, the confidence interval that should be applied to the Canadian estimates is even larger than 0.3 percentage points.

These two estimates are useful when we come to setting the bounds around the productivity point estimates that Statistics Canada produces—when we try to compare differences in productivity growth rates across decades or across countries. This can be illustrated with a concrete example. In 1999, Statistics Canada reported that the annual multifactor productivity growth in Canada over the period 1961 to 1997 was 1.2%, slightly greater than the U.S. rate of 1% over the same period. On the basis of these data the productivity growth rates in the two countries were described as indistinguishable (Wells, Baldwin and Maynard 1999). The reason for this conclusion, despite differences in the point estimates of productivity growth in the two countries, is that the difference between the growth rates in the two countries is within the margin of error that either of the techniques discussed above produces.

The size of the confidence interval that should be applied to the productivity estimates will vary in other situations. If we are trying to assess what the true productivity growth in Canada was in a decade where the estimate was, say 1.2%, then the type of bound outlined above (at least 0.3 percentage points) should be used.

But if we want to argue that recent preliminary estimates for this decade fall below the estimates for the last decade, then we should be aware that past revisions in Canada have changed the productivity growth rates by approximately 0.2 percentage points and therefore our confidence intervals should probably be even larger than 0.3 percentage points—perhaps as large as 0.5 percentage points.

If we want to argue that Canada's productivity growth rate was different from that of another country, then we probably have to expand the confidence interval used for this purpose, if the methodologies in the two countries are different or if productivity statistics are calculated with incorrect labour or capital data. This is the case for international comparisons like those of the OECD, which use imperfect labour input measures.

All of this means that conclusions about changes in productivity trends and differences across countries need to be made cautiously. Productivity measures are first differences of first differences—that is, they are calculated as the difference between changes in output and changes in inputs. Errors in one component can have a magnifying effect on changes in the overall productivity measure. For example, in recent months the rate of output growth in the United States has been revised upward from 3.1% to 3.5% and productivity growth has been revised from 1.2% to 1.6% (Seskin 1999). A 13% error in estimated output growth translates into a 33% error in the estimate of productivity growth. Productivity measures therefore inherently have less precision than the output and input components that enter into the formula and that are used to calculate productivity growth.

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4 Productivity Growth in Canada and the United States

JOHN R. BALDWIN, TAREK M. HARCHAOUI AND JEAN-PIERRE MAYNARD

4.1 Introduction

Productivity statistics are frequently used to compare performance across countries. Interest in productivity growth often focuses not just on how well Canada is doing, but whether it is gaining or falling behind its major trading partners. Intercountry differences like these are useful in understanding the reasons for differences in the standard of living, the competitiveness of national industries, and the causes of trends in the exchange rate. In this chapter, we examine differences in the course of productivity growth between Canada and the United States.

We do so in three different sections. The first section looks at long-run trends in productivity growth in the business sectors of the two countries, over the period 1961-1999. The second section does the same for the manufacturing sector. The first two sections focus on long-run trends in the two economies because short-run data are quite volatile. In the third section of this chapter, however, we examine short-run growth in labour productivity because, since 1995, the growth in the United States has attracted attention.

Before proceeding, it is important to warn readers of the inherent difficulties in cross-country comparisons. Cross-country comparisons of productivity are invariably imprecise because of differences in methodology employed in different countries. Output and inputs are not always measured in the same way. For example, labour can be measured as the number of jobs, the number of people employed or the number of hours worked. Capital input can be estimated using capital stock or the flow of capital services.[1]

Differences in the measurement of output are illustrated by the differences in the treatment of software, between the United States and Canada. Under the latest U.S. methodology, expenditures on software are capitalized whereas under the Canadian conventions they are mainly expensed.

The U.S. Bureau of Labor Statistics provides measures of labour and multifactor productivity that are reasonably comparable to those of Canada. While not exactly the same, they are closer than the estimates available for many other countries and, therefore, provide us with a foundation for a Canada-United States comparison. Nevertheless, it must be remembered that the methodology is not exactly the same and therefore the comparisons are not perfect. We point out differences where they are most relevant.

4.2 Business sector productivity growth, 1961-1999

Comparisons between Canada and United States that are based on labour productivity growth are perhaps the most straightforward. Both Statistics Canada and the U.S. Bureau of Labor Statistics report a labour productivity measure for the business sector.[2] Both countries use GDP as a measure of output, though the United States adopts a measure based on GDP at market prices, whereas Canada uses GDP at basic prices.[3] Both countries use hours worked as a measure of labour input.

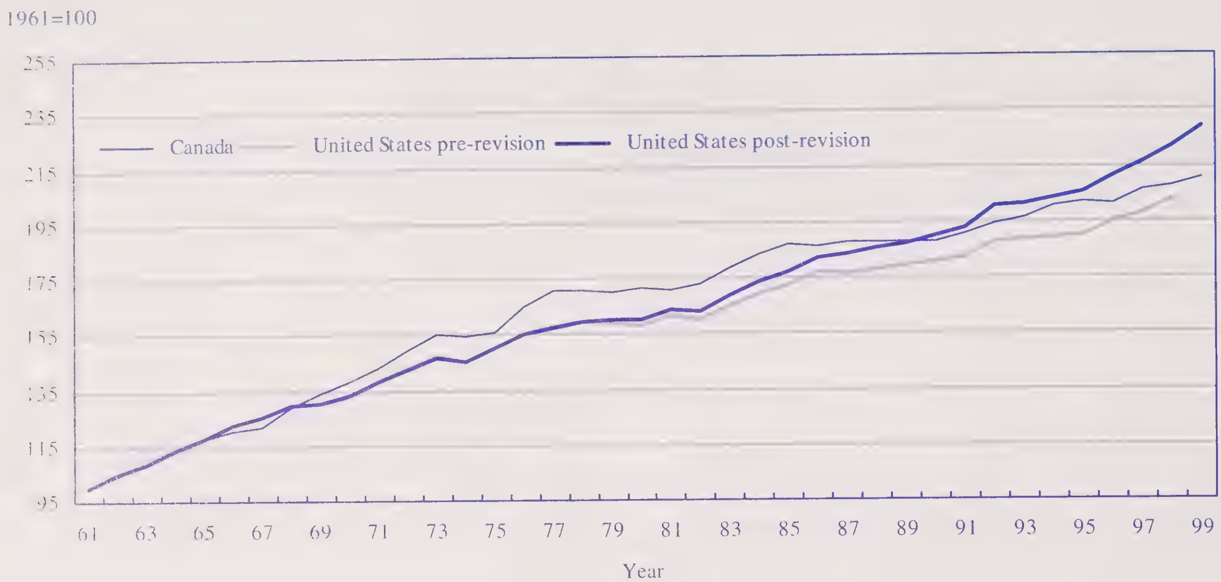
It must nevertheless be recognized that there are some differences in methodology. In particular, the U.S. concept of GDP has recently been revised. These revisions involve the capitalization of software expenditures, and making

[1] The flow of capital services is the flow of services yielded by the capital stock.

[2] In Canada, this calculation excludes a large portion of the health and education sectors. In the United States, the business sector excludes the public education sector.

[3] See Appendix 1 for Canadian methodology.

Figure 4.1 Cumulative growth in business sector labour productivity, Canada and United States



better use of spliced price series to take into account qualitative changes in the consumer price index. Canada uses a similar concept of GDP, except for the former adjustment.

The changes in the U.S. methodology have increased their rate of labour productivity growth by as much as 33%. This new methodology reduces the direct comparability of the two official labour productivity series.

We deal with this problem by reporting two measures of labour productivity for the United States (Figure 4.1). The first utilizes the 1999 estimates that are more comparable with Canadian estimates of GDP.[4] The second uses the revised estimates of the U.S. labour productivity series that was released in 2000, and are less comparable with Canadian GDP.[5]

Year-to-year growth rates are often severely affected by economic cycles and do not provide a very good measure of long-term movements in relative efficiency. For that reason, we plot the cumulative gain in productivity for Canada and the United States since 1961.

A comparison of the growth in labour productivity in the business sectors of Canada and the United States using the cumulative pre-revision series shows that Canada was consistently ahead of the United States from the late 1960s to the present. Although not comparable with their Canadian counterpart, the revised U.S. series indicates the emergence of an increasing gap in favour of the United States beginning in the early 1990s.

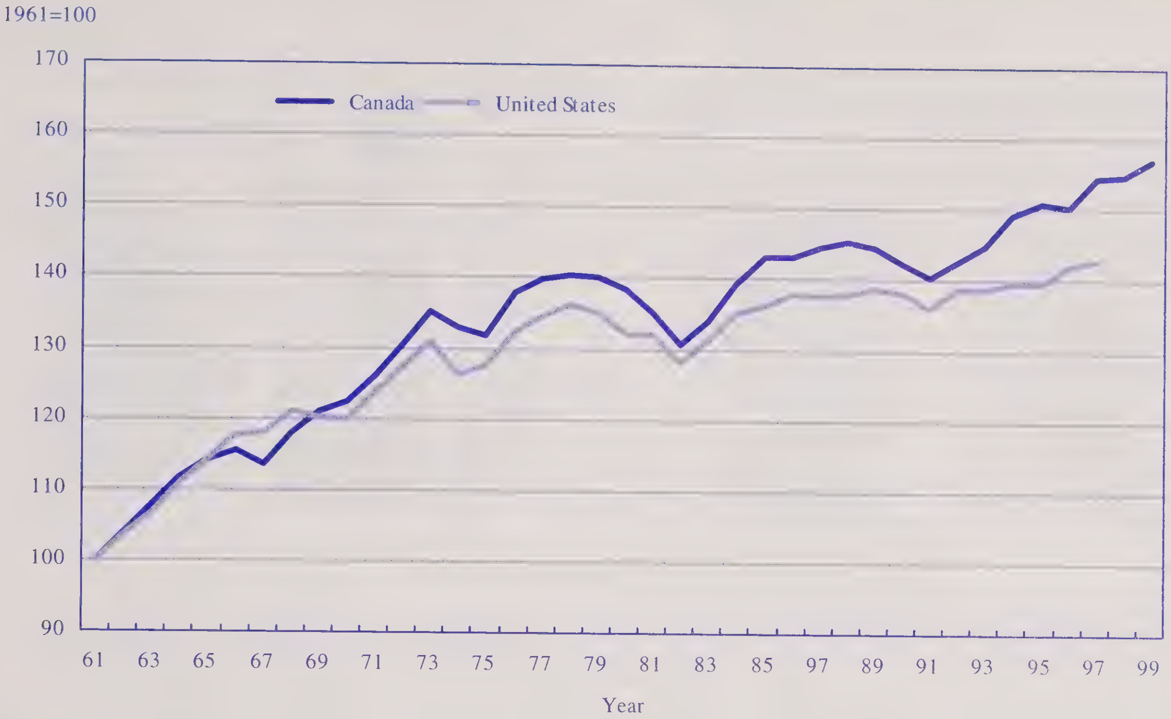
Trends in multifactor productivity growth are more difficult to compare than labour productivity because of larger methodological differences used in constructing these measures.[6]

It should be noted that at the time of this writing, the United States had not revised its multifactor productivity estimates to reflect the new GDP methodology, and therefore we report only one estimate of multifactor productivity—an estimate based on GDP that does not capitalize software.

A comparison of cumulative multifactor productivity growth for the business sector in both countries shows

4 U.S. Bureau of Labor Statistics, NEWS, August 27, 1999.
5 U.S. Bureau of Labor Statistics, NEWS, March 7, 2000.
6 First, the United States makes corrections for the quality of labour in its measures of growth for the economy as a whole that are different from the corrections made in Canada. Second, the methodology underlying the construction of the capital input in both countries is slightly different. The rates of depreciation implicit in the U.S. approach are lower than those derived in Canada. On the other hand, the United States includes land and inventories in its estimate of capital while Canada does not. In addition, Canada assumes that the flow of capital services from a dollar of capital of stock is the same across asset types while the United States does not (see Appendix 1 in this publication). Research is under way to examine the effect of incorporating similar assumptions in the Canadian estimates.

Figure 4.2 Cumulative growth in business sector multifactor productivity, Canada and United States[1]



Note: 1. Based on value added.

Canada growing at a faster rate than the United States (Figure 4.2).[7] Until the early 1980s, there is little difference between the two countries. Since that time, however, Canada has moved *slightly* ahead of the United States. Nevertheless, these differences are not large—less than 0.2% per year—and well within the margin of error that is associated with the estimation of productivity indices (see Chapter 3). We would conclude that, based on this data, there is no evidence of significant differences in overall multifactor productivity growth in the business sectors of the two countries.

It is noteworthy that there are substantial differences in the cyclical effects in the measured rates of multifactor productivity growth. The rates of growth for both Canada and the United States show the effects of the recession in the early 1980s. The recession of the early 1990s had a marginal effect on the rate of productivity growth in the United States, whereas Canada experienced a more pronounced productivity slowdown during this period.

These results imply that Canada-United States comparisons of productivity performance can be quite sensitive to the choice of endpoints. Whether choosing years like 1988 (a peak year) and measuring for short periods through the recession in the early 1990s (a trough year), or doing the same in the early 1980s, short run measurements will give a more pessimistic view of Canada's performance relative to the United States, as compared with longer run comparisons.

In order to investigate the importance of differences in methodology on Canada-United States comparisons, we recalculated the multifactor productivity estimates for Canada and the United States to make them even more comparable. First, we removed the correction for changes in worker quality that is normally included in U.S. estimates. We did the same for Canada.[8] We then recalculated the rate of growth of capital stock for Canada by using the delayed (or hyperbolic) depreciation function that is employed by the BLS in the United States. Next, we

7 Multifactor productivity estimates are based on the official Statistics Canada series and the official series from the U.S. Bureau of Labor Statistics.

8 We did so by calculating the growth rate of the sum of all hours worked across industries as opposed to a weighted sum where the weights are the share of total payroll of each industry (see Appendix 1).

Figure 4.3a Business sector multifactor productivity growth[1], Canda and United States, 1961-1997

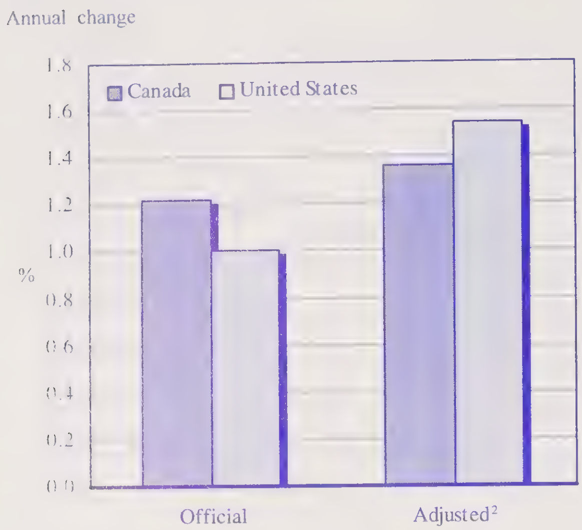
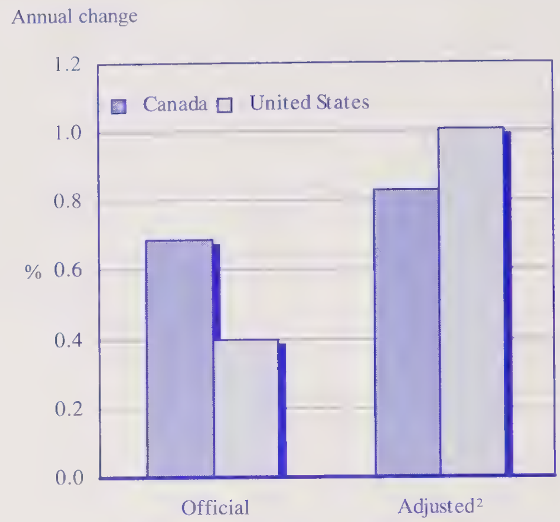


Figure 4.3b Business sector multifactor productivity growth[1], Canada and United States, 1988-1997



Notes: 1. Based on value added.
2. For both countries, labour input and capital input are measured, respectively, as the sum of hours and the sum of capital stock net of hyperbolic depreciation (machinery and equipment and structures).

calculated the rate of capital growth for the United States, using the sum of productive capital stock (not the sum of capital services), and using only the categories used in Canada—namely, machinery and equipment, and structures. We use the estimates of GDP growth excluding software investments for the United States. Finally, we compared the Canadian rates of productivity growth with that of the United States, using the official estimates of the two countries and these more comparable estimates (adjusted). This is done in Figure 4.3a for the period 1961-1997, and in Figure 4.3b for period 1988-1997.

Over the entire time period, the official estimates show Canadian performance exceeding that of the United States (1.2% and 1.0%, respectively). The differences are within the margin of error that must be ascribed to uncertainty (see Chapter 3). When the estimates are adjusted for comparability, Canada falls slightly behind the United States (1.4% and 1.6%, respectively). However, the differences between the two countries are still within the margin of error. Over the period 1988-1997 (Figure 4.3b), the same trend emerges. Canada and the United States follow essentially the same productivity growth path and the differences are still within the margin of error described in Chapter 3.

On balance, these data show substantial similarity in the growth of productivity between the Canadian and the U.S. economies over the last 40 years. Several factors contribute to this: the proximity of the two economies, the large amount of foreign investment that leads to technology transfer, similarities in the available technologies, and the close trading relationship that exists between Canada and the United States.

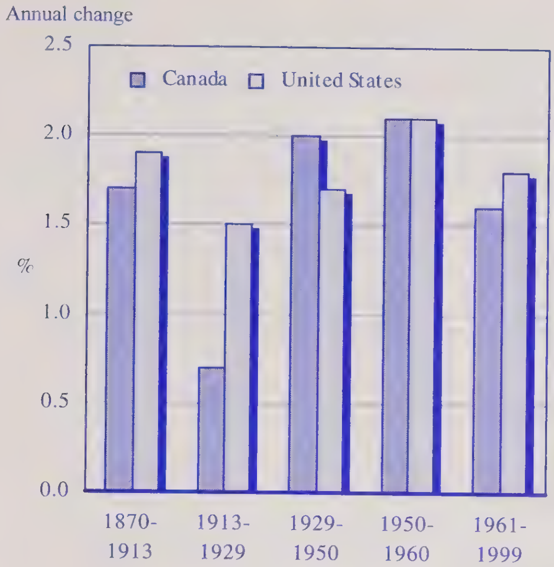
Is there something special about the period since 1960? Did we perform more or less well in previous periods when the two economies were less integrated, when Canada's trade was more closely oriented with England and the British Commonwealth, when the economy was more heavily reliant on the extraction of natural resources?

To answer this, we examine historical trends in labour productivity[9] dating back to the years just after Confederation (Figure 4.4).[10] It is clear that similarities in labour productivity growth have been with us since that time.

[9] For purposes of historical comparability, labour productivity is defined here using total GDP divided by employment and not business sector GDP divided by hours worked as was done in Figure 4.1. We utilize the 1999 estimates of U.S. GDP that are closer to the Canadian methodology.

[10] For this graph, the Canada-United States comparisons are taken from the U.S. Department of Commerce (1975), which based its comparisons on Angus Maddison's work *Economic Growth in the West* done for the Twentieth Century Fund. The comparisons prior to 1960 use GNP for the entire economy. Those after 1960 use GDP for the business sector.

Figure 4.4 Output per employee



Except for the period after World War I, Canada has consistently tracked the labour productivity performance of the United States. Despite our distinctiveness in terms of trade orientation with Britain before World War II, our greater reliance on natural resources, and our adoption of a more comprehensive social safety net, our productivity growth has increased by about the same amount as that of the United States in just about every major phase of our industrial history. While a slowdown has occurred in the period after OPEC, our slowdown is the same as that of the United States.

4.3 Productivity trends in manufacturing, 1961-1999

The manufacturing sector tends to get special attention in intercountry productivity comparisons, partly because of its importance in trade relations with the United States, and partly because of the impact of the Canadian-U.S. dollar exchange rate on that sector.

As mentioned earlier, the United States uses GDP at market prices, and a perpetual inventory type capital stock calculated net of depreciation that places different weights on different types of capital stock via the use of a rental rate of capital. Unlike its estimates for the business sector, however, the United States adopts hours worked with no adjustments for labour quality at the sector level.

The Canadian data use GDP at basic prices, a perpetual inventory type capital stock technique that weights equally all assets and hours worked. Improvements in labour quality are included in the Canadian hours worked estimates via the industry weighting scheme that is used for aggregation purposes.

Estimates of multifactor productivity growth in the manufacturing sector of Canada and the United States are presented in Figure 4.5. Productivity growth in the United States experienced robust growth in the early 1970s, followed by a period of slower growth in the late 1970s. In contrast, productivity growth in Canada experienced relatively faster growth in the earlier period followed by slower growth. The performance of the U.S. manufacturing sector jumped ahead of Canada during the growth phase of the 1990s recovery, when productivity growth of the United States slightly exceeded that of Canada.

There is substantial two-way trade that ties the economies of Canada and the United States together. Over 60% of Canadian manufacturing shipments is accounted for by foreign-owned companies. In these circumstances, it is likely that gains in knowledge that lead to increases in productivity will be quite similar, though not identical.

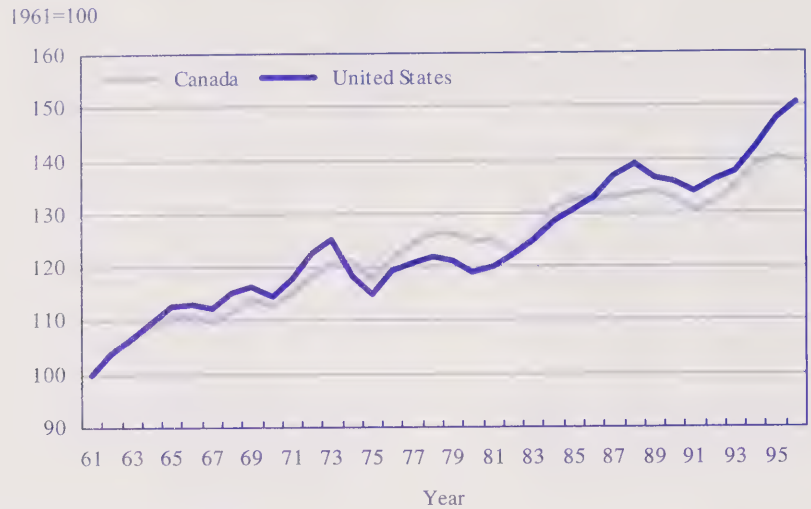
One way to test this is to ask how the experience of different industries is related over time. To accomplish this, we developed multifactor productivity measures for a set of 17 Canadian manufacturing industries that corresponded to comparable published data for 17 U.S. industries at the two-digit SIC level.

In order to investigate the relationship between the two countries, we correlated the productivity performance of these seventeen industries over the period 1961-1996. Over the entire time period, the correlation between the growth of Canadian and U.S. industries was close to 0.7, indicating that on an industry-by-industry basis, there is evidence to show that the same forces have been at work in both Canada and the United States.

Despite these similarities, it is still useful to examine the growth rates in Canada and the United States during the pre- and post-1992 periods so as to confirm whether there is any indication of general similarities across most industries or whether there are any major industry-specific differences (Figure 4.6a and 4.6b).

Before 1992, there is an obvious similarity in the performance of the manufacturing industries of both countries (Figure 4.6a). In general, the industries with the highest Canadian productivity growth rates also have the highest productivity growth rates in the United States. However, there are some noteworthy differences. In the United States, the machinery and electronics industries grew at almost twice the rate of every other industry, and considerably

Figure 4.5 Cumulative growth in manufacturing sector multifactor productivity[1], Canada and United States, 1961-1996



Note: 1. Based on gross output net of intra-industry sales.

more than its Canadian counterpart. In about half of the industries, productivity growth in Canada is higher than the United States.

If we turn to the post-1992 period and perform the same comparison (Figure 4.6b), it is apparent once again that there is a large difference in two areas—machinery and equipment, and electrical and electronic products. It is noteworthy, however, that U.S. productivity growth in the latter industry dominates that of all other industries in the United States.

The electrical and electronic products industries in the United States contain the bulk of the computer industry. But it should be noted that these are the two sectors where hedonic price indices have been used to account for quality improvements.

The number of industries in which Canada is leading dropped significantly (from 10 in the pre-1992 period to 5 in the post-1992 period), but the performance of Canada remains close to the United States in the largest traditional industries such as paper and allied products, chemicals, and primary metals.

4.4 Performance of the business sector, 1995-1999

The previous sections have examined the differences in long-run productivity trends in Canada and the United States. We focus on long-run trends because short-run data are less accurate and subject to more error because of revisions (see Chapter 3). Nevertheless, in recent years, a marked difference has emerged in U.S. productivity growth that must be noted.

Since 1995, U.S. growth in labour productivity has moved well above its long-run post-1973 average of 1.5%. In the four years after 1995, the U.S. economy has experienced record shattering labour productivity growth rates of 2.8%, 1.9%, 2.9%, and 3.2%, respectively (Figure 4.7).

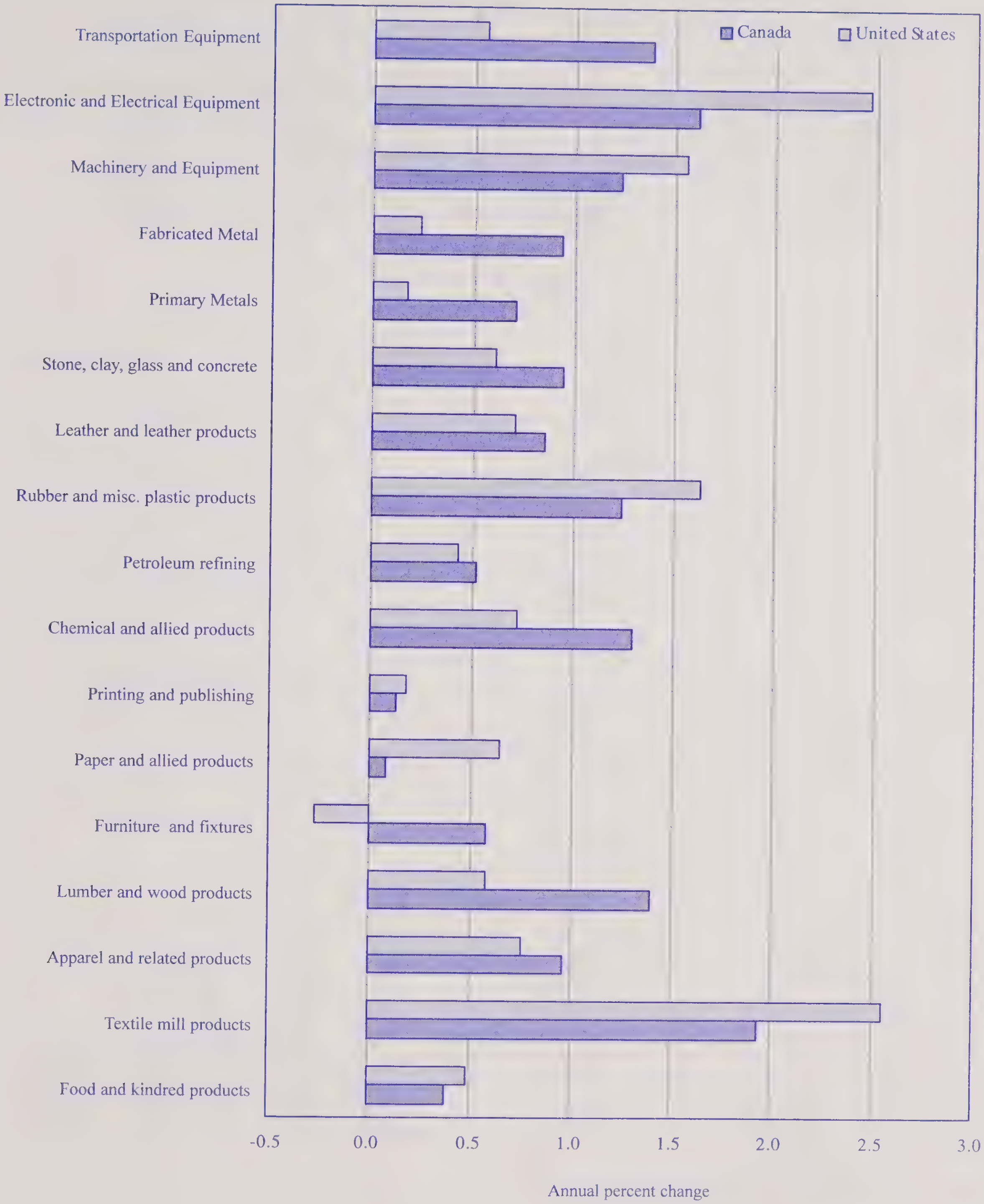
Comparisons of labour productivity between Canada and United States over the most recent period have been affected by recent changes in the definitions and in the statistical methodologies that were incorporated into the United States National Accounts with the completion of their 1999 historical revisions.

These changes have increased the annual rate of U.S. GDP growth from 2.8% to 3.3% annually, between 1978 and 1998. In turn, this has increased the U.S. estimates of labour productivity over the same period from 1.2% to 1.6% annually. The 18% revision in U.S. GDP growth rates translates into a 33% increase in productivity growth. Almost half of the increase arises from the inclusion of software investments.[11]

Both the old and the new estimates of U.S. business sector labour productivity growth are presented in Table 4.1. Prior to the U.S. revisions, Canada performed slightly better than the United States over the period 1961-1978 (3.2% versus 2.8% annually, respectively), and slightly worse than

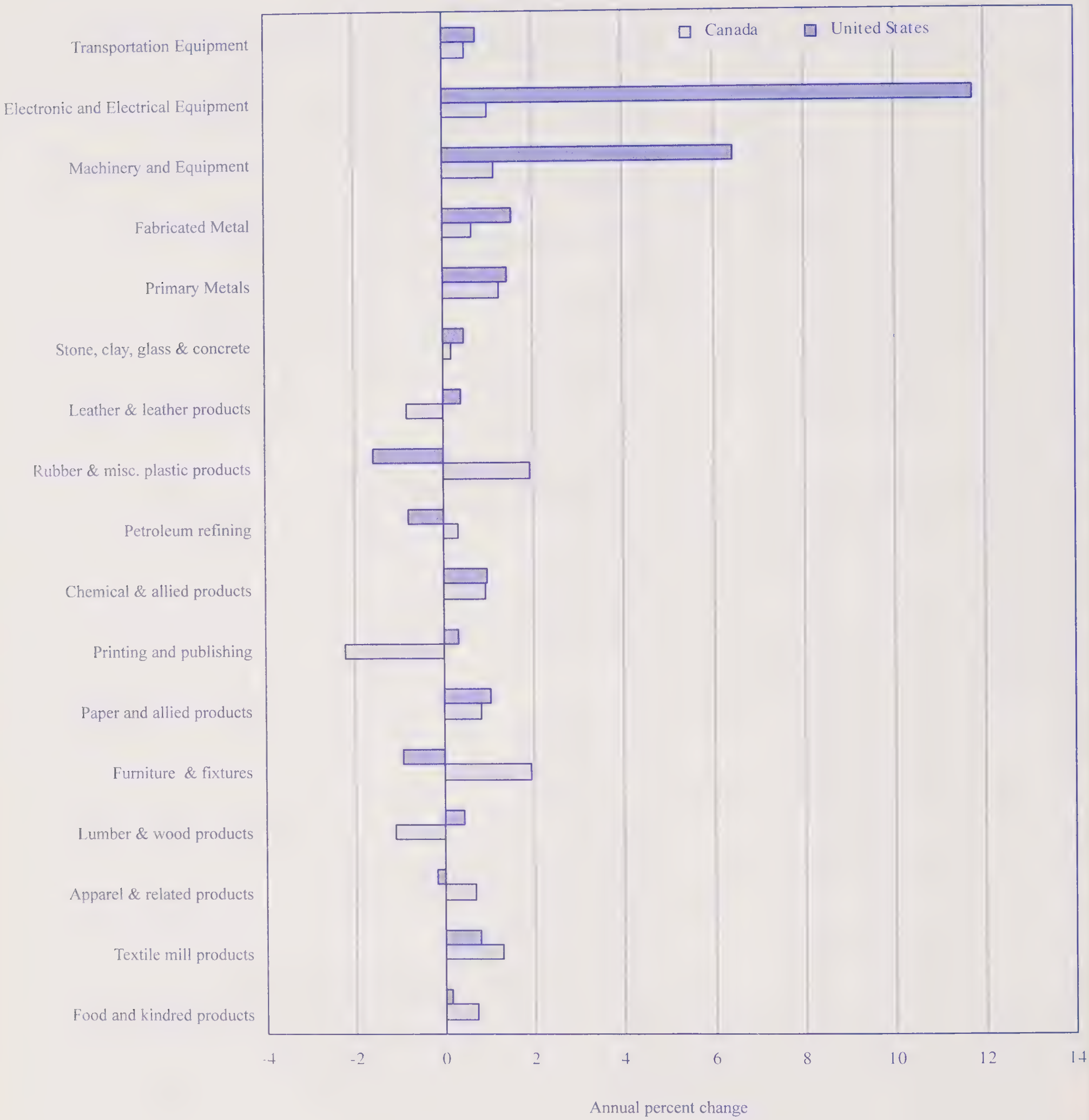
[11] Parker and Grimm (2000).

Figure 4.6a Manufacturing sector multifactor productivity growth[1], Canada and United States, 1961-1992



Note: 1. Based on gross output net of intra-industry sales.

Figure 4.6b Manufacturing sector multifactor productivity growth[1], Canada and United States, 1992-1996



Note: 1. Based on gross output net of intra-industry sales.

Table 4.1 Comparison of business sector labour productivity growth, Canada and United States, 1961-1999

	annual growth rates (%)		
	U.S previous	U. S. new	Canada
1961-1978	2.8	2.8	3.2
1978-1998	1.2	1.6	1.0
1978-1999	..	1.7	1.0
1996	2.7	2.8	-0.1
1997P	1.4	1.9	2.4
1998P	2.4	2.9	0.5
1999P	..	3.2	1.4

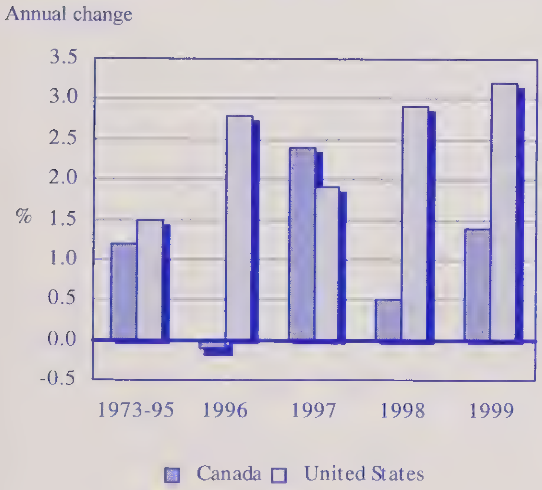
Note: .. Figures not available.
P Preliminary.

the United States over the period 1978-1998 (1.0% versus 1.2%, respectively).

After the revisions to the productivity estimates in the United States,[12] productivity growth in Canada is further behind that of the United States over the latter period.

Preliminary estimates of Canadian and U.S. productivity for recent years suggest a widening gap between the two countries. Though subject to revision, these estimates show that Canadian labour productivity over the last four years has grown at a cumulative rate of 4.2%, whereas the United States experienced a cumulative growth rate of 11.5%. Even before the U.S. historical revisions, U.S. labour productivity growth during these years was above Canadian growth and continues to be so by a considerable margin (Figure 4.7).

Figure 4.7 Business sector labour productivity growth in Canada and the United States—selected periods



4.5 Conclusion

Productivity growth in the economy is an important contributor to improvements in our standard of living. It is affected by small, incremental changes in a host of factors that occur on the plant floor. These include new production techniques, changes in plant size, changes in organization as well as other factors that are associated with new knowledge.

These changes are generally not cataclysmic. Even momentous changes involving new technologies take time to implement. These changes are relatively steady, when measured over long cycles. Since the First World War, the annual growth rates of labour productivity have averaged very close to 2% per year. They slow down after 1973—but the slowdown in Canada has been much the same as in the United States.

What is remarkable about the historical performance of productivity growth in the Canadian economy is its similarity to that of the United States. During different periods when we have experienced war and peace, a transition to a society that has a stronger safety net and other societal changes, the rate at which new knowledge has been incorporated into the production process has been relatively steady and about the same as the United States. Over almost 40 years since the 1960s, Canada has continued to move in step with the United States. This has occurred at the same time that trade has become more liberalized between the two countries. Moreover, the similarities in performance extend back over 100 years when measured over long periods.

[12] No corresponding revisions were made in Canada.

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5 Heterogeneity in Labour Productivity Growth in Manufacturing: Differences Between Domestic and Foreign-controlled Establishments

JOHN R. BALDWIN AND NAGINDER DHALIWAL

5.1 Introduction

Discussions of productivity usually focus on economy-wide aggregates. The course of these aggregate measures is determined by the performance of sub-populations. Since differences in labour productivity reflect differences in technology, capital intensity, size, and other firm-specific factors, it is important to look at how Canadian productivity performance differs across subgroups if we are to detect underlying weaknesses. In this chapter, we focus on differences in two major subgroups of the overall population—establishments that differ by size and by nationality of control.

An examination of productivity differences across size classes is important since job growth in the manufacturing sector has been predominantly concentrated in small establishments (Baldwin and Picot 1995). However, labour productivity is lower and falling in small establishments relative to large establishments (Baldwin 1998). The growth in the share of employment in small establishments, therefore, would have had the effect of slowing labour productivity growth in the manufacturing sector (Baldwin 1996).

An analysis of productivity differences by nationality is equally relevant since foreign-controlled firms are mostly large and capital intensive, and are often seen as the vehicle through which new technologies are incorporated most quickly into the economy. These firms account for about 55% of shipments in the manufacturing sector in 1993 and, therefore, have an important impact on both aggregate labour productivity and job growth.

5.2 The importance of foreign control

The policy regime that affects foreign investment in Canada has changed over the last 20 years in two ways. First, trade liberalization has seen tariffs gradually fall. The Kennedy round of General Agreement on Tariffs and Trade (GATT) tariff reductions was felt in the 1970s and the Tokyo round followed in the 1980s. These two multilateral rounds of tariff reductions were followed by bilateral tariff reductions between Canada and the United States in 1989 as a result of the Canada-U.S. Free Trade Agreement (FTA) and then the North American Free Trade Agreement of 1992 (NAFTA).

While tariff reductions lessened the barriers to the movement of goods, changes in the investment regulatory regime have reduced barriers to the movement of capital. Prior to 1983, the Foreign Investment Review Agency regulated foreign investment. In 1983, this was replaced with a new agency (Investment Canada), whose mandate was seen to be less restrictive in the sense of facilitating and soliciting foreign investment rather than controlling it. At the same time, foreign investment provisions of both FTA and NAFTA changed the thresholds required for review before the agency.

Liberalized trade and regulatory regimes might be expected to affect foreign direct investment in a number of ways. First, reductions in regulation decrease the cost and uncertainty involved with foreign investment and should be expected to increase investment. Second, tariff reductions allow firms greater flexibility in optimizing their production facilities. Whether this would result in foreign operations leaving Canada depends on whether the Canadian market can be better served from abroad or with production facilities in Canada once tariffs are decreased, and whether Canada has a comparative advantage in some areas that would lead production to be located here.

Traditional theories of foreign trade try to answer this question by focusing on the extent to which country-specific factors that determine the costs of business affect the pattern of international trade. The costs of business are determined by factor endowments, production processes,

transportation costs, tax and regulatory regimes. These comparative advantage theories are not ideally suited to explain the creation of the multinational firm—an organization that has production facilities in different countries. In response, a theory of transnational firms has been developed to explain why firms internalize transactions across national boundaries rather than engage in arm's-length trade.

One strand of this literature focuses on the existence of assets that are difficult to trade—either because these knowledge-based assets lead to asymmetric information difficulties or problems in writing contracts, evaluating results and monitoring performance. These assets could involve proprietary production technology, unique marketing skills, trademarks, or brand names (Caves 1982). Because assets are assumed to be difficult to exchange efficiently via market mechanisms, firms are seen to set up shop abroad rather than sell or license rights for use of their assets by local firms in foreign markets.

In this vein, Dunning (1993) argues that a multinational enterprise (MNE) will develop if there are compelling reasons for a firm to internalize economic activity rather than to rely on markets. These could be related to the difficulty of exchanging company-specific assets through the marketplace. Alternately, there may be efficiency reasons for undertaking foreign direct investment (FDI). Just as a single-nation firm internalizes some economic activity for reasons of efficiency (e.g., keeping a pay division on staff rather than contracting out payroll services), so too an MNE may obtain efficiency gains by bringing together various internationally dispersed entities under common ownership. In still other cases, the opportunity to ensure a steady supply of inputs or a guaranteed market for outputs through vertical integration may be a compelling reason to internalize economic activities.

Thus, foreign investment in Canada may have changed over the last 20 years for several reasons. First, regulatory policy changes may have changed the profitability of foreign direct investment. Second, the reduction in tariffs may have influenced the relative cost of doing business in Canada and changed the incentive to internalize production.

Of course, changes in other fundamentals may also have affected foreign investment in Canada. First, outsourcing has increased in some industries—particularly in industries selling branded products where firms have learned that they can reduce costs by contracting out their manufacturing operations. This is evidence of a reduction in the benefits of internalization, which should result in a reduction of transnational investment. Second, the stability of developing markets has increased over the last 30 years and, therefore, the relative advantage of Canada as a secure source of raw materials over production facilities in developing markets has decreased. In turn, multinational investment in some sectors could have shifted away from Canada. Third, the importance of knowledge assets may have increased as the result of the type of technological progress taking place. As advanced computer-based technologies have been incorporated into the production process, knowledge assets are seen by some to have become more important.[1] This, in turn, would have increased not only the benefits from and extent of internalization, but also the amount of multinational investment in Canada.

In order to assess how these and other changes have affected the role played by foreign-controlled firms in Canada, we first investigate how their share of Canadian manufacturing sector output has changed over time. Their market shares are derived from establishment data, taken from the annual Survey of Manufactures, which classifies each plant by ownership type—domestic or foreign-controlled.[2] The changes in the importance of foreign-controlled firms in the Canadian manufacturing sector over the period 1973 to 1993 are measured using both shipments and value-added (Figure 5.1). We also report their share of labour inputs—defined as the sum of production and non-production workers.

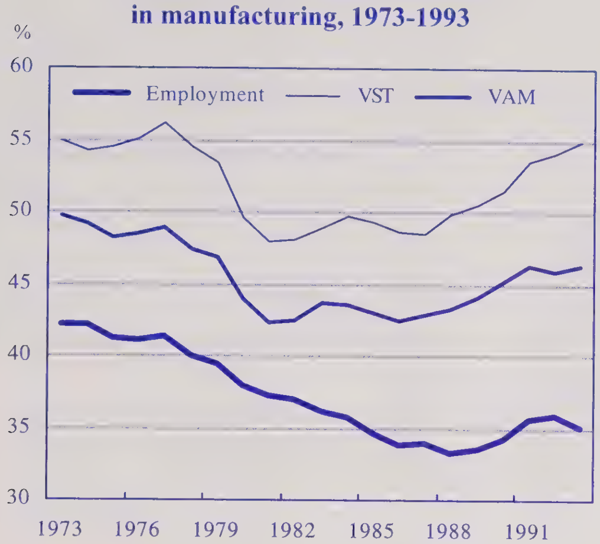
Before 1980, the share of output in manufacturing accounted for by foreign-controlled firms declined and reached low points in 1981 and 1982. Subsequently, there was a steady increase in output share. While the foreign share of output has increased, its share of employment has decreased continuously. The relative labour productivity (defined in terms of output per worker) has, therefore, increased (see Figure 5.2). Except for the two recession-related downturns, the increase has been more or less steady over the entire time period. An increase in the relative wage per worker paid by foreign-controlled plants has accompanied this increase in relative labour productivity.

Thus, the foreign-controlled sector has been holding its own with respect to output share, but its employment share has been steady or declining. As a result, labour productivity has been increasing more rapidly in the foreign than the domestic sector.

[1] Baldwin, Gray and Johnson (1996b) show that training is much more intense in firms that are adopting the new computer-based technologies.

[2] These data provide a finer level of industry detail than is provided by classifications that use firm-based data, such as those provided by the *Corporations and Labour Unions Returns Act* (CALURA).

Figure 5.1 Percentage of employment, shipments (VST) and value-added (VAM) of foreign-controlled establishments in manufacturing, 1973-1993



The aggregate data that are presented in Figures 5.1 and 5.2 may hide a great deal. It may be that changes in foreign ownership simply reflect the changing importance of different industries. Therefore, we present changes in foreign shares (shipments) across six industry sectors for three subperiods (1973-1983, 1984-1988, and 1989-1993) in Figure 5.3. These sectors are the food and beverage, natural resource, labour intensive, scale-based, product-differentiated and science-based sectors.[3] It is evident that the importance of foreign-controlled plants followed generally the same pattern in most sectors—one of decline from the 1970s to the 1980s and then a subsequent increase.

In Figure 5.4, we present the change in the relative labour productivity (measured as shipments per worker) of foreign and domestic controlled establishments in each of these sectors. Once again, there has been a general increase in the relative productivity of foreign establishments compared to domestically owned establishments.

The differences between the productivity of foreign and domestic plants can originate from different sources, such as different technologies, more capital and different plant sizes. Here we consider whether size and industry differences explain much of the differences in relative productivity and changes therein.[4] Foreign plants are larger than domestic plants and larger plants are generally more capital intensive and therefore have a higher labour productivity. Foreign plants are also more concentrated in certain sectors (scale-based) than are domestic plants (see Figure 5.3) and the latter sector is among the more capital intensive (Baldwin and Rafiquzzaman 1994).

Both of these factors would make the labour productivity of foreign plants higher than domestic plants. We can determine how much of the total difference between the two groups is the result of differences in composition by comparing the coefficients on foreign control using the following regressions:

$$\text{Log (Labour productivity)} = \alpha + \beta\ (\text{Foreign control}) \quad (1)$$

$$\text{Log (Labour productivity)} = \alpha + \delta\ (\text{Foreign control}) + \gamma\ (\text{Size}) + \eta\ (\text{Industry}) \quad (2)$$

In these equations, Foreign control is a binary variable taking on a value of 0 if domestically controlled and 1 if foreign-controlled; Size consists of three binary variables for the three groups used in this chapter—0 to 100 employees, 101 to 250 employees, and more than 250 employees—and Industry consists of five binary variables for the following sectors: labour intensive, natural resources, product-differentiated, scale-based and science-based. The five groups are defined on the basis of the primary factors affecting the competitive process in each sector. For the resource-based sector, the primary factor affecting competition is access to abundant natural resources. For the labour intensive sector, it is labour costs. For scale-based industries, it is the length of production runs. For differentiated goods, it is tailoring production to highly varied demand conditions. For science-based industries, it is the rapid application of scientific advance.

The ratio of foreign to domestic value added when no account is taken of size class or industry is provided by the coefficient attached to foreign control in equation (1)[5] and reported in columns 2 and 5 of Table 5.1. The ratio of foreign to domestic value added when account is taken of size class and industry differences is provided by the coefficient attached to foreign control in equation (2) and reported in columns 3 and 6 of Table 5.1.

To test whether the choice of output measure matters, we employ both shipments per worker and value added per worker and perform regressions (1) and (2) on micro-data derived from the Census Annual Survey of Manufactures using ordinary least squares (OLS).[6]

[3] See Baldwin and Rafiquzzaman (1994) for a discussion of the definitions in these sectors.

[4] Globerman, Ries and Vertinsky (1994) use micro-data for a limited number of industries to argue that most of the differences relate to size and capital intensity, the latter being proxied by energy use.

[5] The value of the ratio of the labour productivity of foreign to domestic plants is given by exponent β.

[6] For this purpose, we use all production establishments.

Table 5.1 The ratio of the labour productivity of foreign to domestic plants: Effect of controlling for size and industry differences, 1973-1993

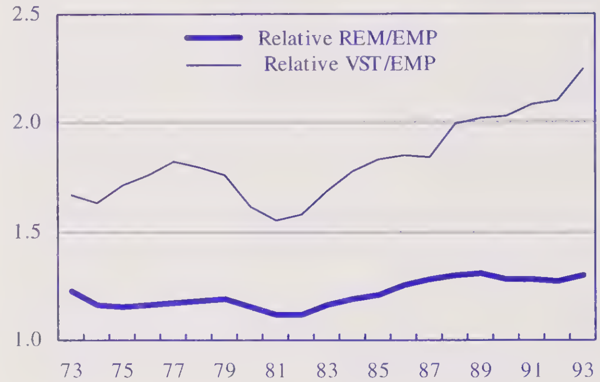
Year	Shipments per worker			Value added per worker		
	No control	Control for size and industry	Difference	No control	Control for size and industry	Difference
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1973	1.80	1.73	0.07	1.66	1.57	0.09
1983	2.09	1.90	0.19	1.92	1.73	0.19
1989	2.22	1.96	0.26	2.12	1.86	0.26
1993	2.27	1.96	0.30	2.07	1.80	0.26

Comparing the results with and without allowance for differences in size and industry reveals that size and industry account for some of the difference between foreign and domestic plants. In 1973, shipments per worker in foreign plants were 80% higher than in domestic plants when no account is taken of size and industry differences and 73% after. The comparable figures for value added per worker were 66% and 57%.

In Figure 5.2, we demonstrated that output per worker in foreign plants as a group went up relative to domestic plants using the weighted average output per worker of foreign and domestic plants. Those results are similar though not identical to the OLS results presented in column 2, Table 5.1 that use individual micro-data that do not allow for industry and size differentials. The latter shows an increase of overall foreign productivity from a level in 1973 that is 80% higher than domestic labour productivity to a level in 1993 that is 127% higher. When account is taken of size and industry composition, there still is an increase in the relative productivity of foreign-controlled plants. After size and industry controls are used, shipments per worker in foreign plants increase from 73% to 96% higher than domestic plants. Using value added per worker, the increase is from 57% to 86% (Table 5.1, column 6). Both of these increases are statistically significant.

Part of the changes in the productivity differences between the two groups arise from changes in the composition of domestic and foreign plants by size and industry. The amount that is attributed to compositional effects is found in columns 4 and 7 representing the difference between the results with and without controls for plant size and industry. It is apparent that this difference widens over time. Between 40% and 50% of the increase in the overall difference between foreign and domestic stems from this compositional shift.

Figure 5.2 Relative remuneration (REM) and shipments (VST) per employee (EMP) – foreign divided by domestic establishments, 1973-1993



These data then show that the overall differences between foreign-controlled and domestically controlled plants are not just the result of compositional shifts. It nevertheless might be the case that differences between the two groups occur disproportionately within subpopulations. In the following sections, we examine the differences in marginal labour productivity and differences in the growth rates of labour productivity across different size classes and different industries.

5.3 The conceptual framework

We are focusing primarily on differences in labour productivity and its growth across establishments that differ in terms of size and nationality, but we also divide establishments into those that are expanding and those that are contracting.

Figure 5.3 Foreign-controlled market share (VST) by sector

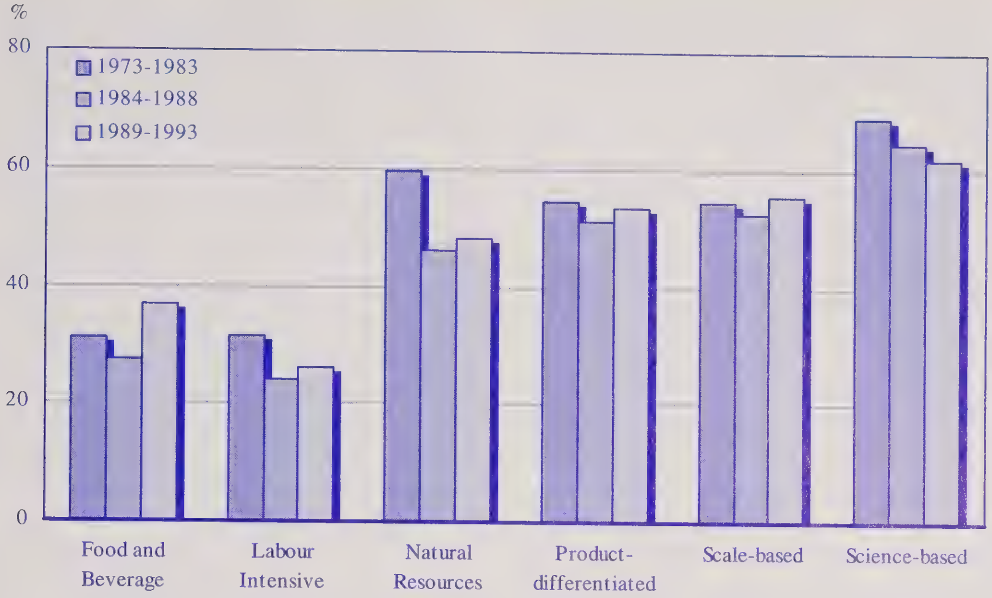
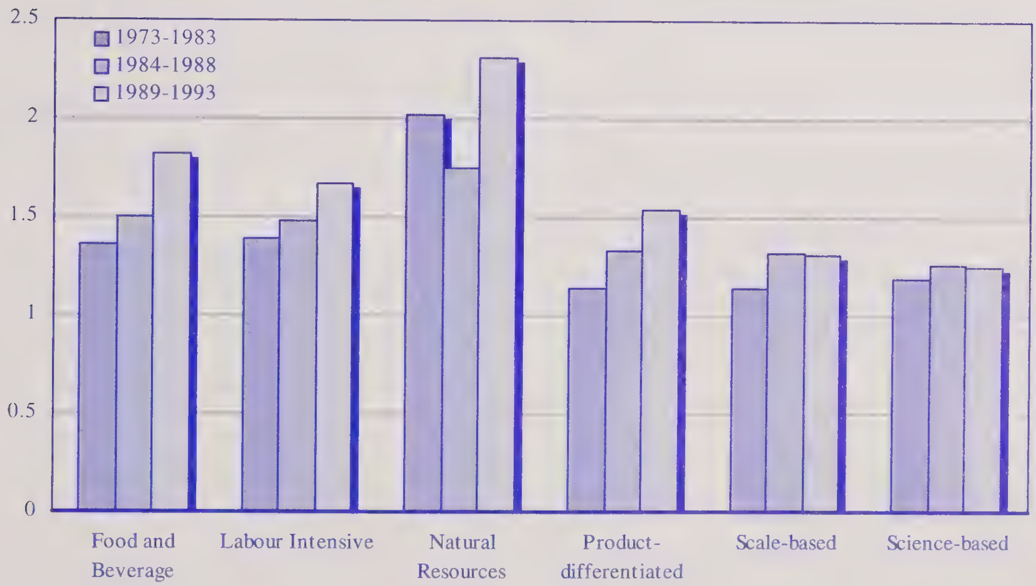


Figure 5.4 Relative output per worker – foreign relative to domestic



We do so because productivity growth is not spread evenly across all establishments. In any population of establishments, some will be increasing productivity and others will be falling behind. When those establishments that are expanding their productivity are also increasing their relative importance because they are growing in relative size, this process of expansion will contribute to productivity growth (Baldwin 1995).

Previous work has examined the proportion of productivity growth that can be attributed to different groups of establishments—entrants (Baldwin and Gorecki 1991)—or to market share being shifted from one incumbent to another (Baldwin 1995, 1996). In these previous studies, incumbents were divided into those gaining and those losing market share. Here, we initially divide the population into two different groups of establishments—those where jobs are being created and those where jobs are being eliminated.[7] This choice is determined by the intrinsic interest in each. Job creation is generally regarded favourably, job contraction, unfavourably.

As attractive as this classification may be, care must be exercised in making inferences from it about who is doing well and who is doing poorly. The job performance of firms is ineluctably connected to both output growth and productivity change. Job change at the establishment level is determined by how the demand for labour varies with output change. That very connection means that it is difficult to make generalizations about performance using job growth and job contraction categories by themselves.

For example, falling employment is sometimes seen as the sign of a failing firm. Yet, a firm that faces a stagnant market and radically changes its technology to improve productivity will often reduce employment. This type of firm cannot be characterized as a failure. Similarly, a firm that is expanding employment in lock step with expanding output would be judged to be performing well (if only employment is examined). Yet its productivity may not have changed.

Often, firms in the early stages of their life cycle focus more on product innovation than cost-cutting process innovation and they have to expand inputs dramatically just to keep up with the growth in market demand. As a market matures, continued growth requires a firm to move away from pure product innovation to process innovation. At this stage, firms implement productivity improvements that will reduce unit costs and allow them to expand output during the mature phase of the market when price competition becomes more important as a marketing instrument. A firm that fails to achieve unit cost reductions via productivity improvements will not survive the transition from the early to the later stages of market development.

At any time, the population is made up of some firms that are in the early phases of market development, and others that are in the later stages, operating in relatively mature markets. If firms are adapting successfully to the later stages of the life cycle, they will be increasing productivity and reducing unit costs by reducing their requirements for labour per unit of output, for example. Often this is done by increasing capital intensity. Sales of firms at this stage may also have reached a plateau. Other firms will be in their growth phase, when it is all they can do to keep up with growing demand, where innovative activities focus more on product innovation than on cost-based process innovations. The latter group of firms will probably have less productivity growth because they are still expanding rapidly and have not yet moved to the mature phase of the market where competition is based more on prices than on new-product introduction.

Therefore, a decline in employment in a firm is not necessarily evidence of the decline of the firm. It may be associated with productivity gains during the mature phase of the life cycle. An examination of employment change alone does not allow us to conclude the reasons for employment change. If we are to study employment change and how firms respond to output change, we must be cognisant of the extent of heterogeneity in the population and the various reasons that a firm may be increasing or decreasing employment.

5.4 Data description

The data used in this analysis are taken from the micro-economic records collected by the Census Annual Survey of Manufactures and a longitudinal database that was created by the Micro-economic Analysis Division, covering the period 1973-1993. Focusing on establishment data is advantageous because it allows us to move closer to the product or business line than would be the case if firm-level data were used. Because firms are constantly merging and divesting themselves of plants, a good portion of their growth occurs as a result of these control changes. For this analysis, we want to avoid these effects.

[7] Bailey, Bartelsman and Haltiwanger (1996) also use this distinction.

In this data set, the records for individual establishments are linked through time, allowing the dynamics of establishments to be investigated.[8] The establishments can be classified by four-digit industries using the Standard Industrial Classification (SIC) system, nationality of control (domestic versus foreign),[9] and size (small, medium, and large).[10] The size codes were assigned each year, allowing establishments to switch from one size category to another as they grow or downsize over time. The four-digit SIC industry codes were grouped into five broad sectors—natural resources, labour intensive, scale-based, product-differentiated and science-based. The natural resource sector was further partitioned into two subsectors—food and beverage and 'other' natural resource industries. In all, these classification criteria grouped the manufacturing establishments into 36 categories; i.e., 6 sectors, 3 size classes and 2 types of control (Canadian and foreign).

Establishments were grouped into those where employment was increasing and those where employment was decreasing. Employment, employment changes, shipments, and shipment changes were calculated at the level of the 36 categories.[11] For example, one data set consisted of job growth and output change for each of these 36 categories for 20 years; the other for job loss and associated output change. Job growth encompassed both entries and changes in continuing establishments. Job contraction consisted of both exits and changes in continuing establishments.

In this chapter, it is assumed that labour productivity will grow because of increases in the inherent efficiency of a firm, as well as increases in the amounts of other inputs that are combined with labour—in particular the amount of capital that is available per unit of labour.

Change in output is measured in terms of changes in total shipments. Employment is measured as the total number of workers (salaried plus production workers). Alternatives could have been chosen; for example, we could have used value added as defined in the Census Annual Survey of Manufactures. The latter concept includes some purchased services and thus is not identical to the net value added concept that is used in generating GDP and the values used in the official productivity statistics. Shipments as a measure of output, has the disadvantage that increases in shipments per worker may simply hide a decrease in the degree of vertical integration over time. For the purposes of this analysis, it turned out not to matter much which measure of output was used, and, therefore, we have chosen to report the measure used herein.[12]

Changes in shipments were expressed in real terms, with the nominal values of each establishment being deflated by the four-digit output price index for the industry in which the establishment is classified.

This chapter examines changes in labour productivity over time. These changes are investigated for short time periods and longer time periods since experience has shown that the former are expected to heavily reflect random events and the latter are more useful for distinguishing trends (Baldwin and Gorecki 1990). The short-run analysis is based on a year-to-year change in the relevant variables, generating a time series for the period 1973-1993. For the long-run analysis, the changes are measured using a five-year moving average, generating a time series of 16 observations for the 1973-1988 period. Establishments were allowed to move freely from one time period to the next between the job creation and job elimination categories.

5.5 Labour productivity

This section investigates how the productivity of labour changes as a result of the growth and contraction process. Growth and contraction are treated separately. The population is divided into those with growth and contraction in output as opposed to growth and contraction in employment to avoid selection effects when estimating marginal labour productivities (Hamermesh 1993 and Heckman 1979).[13]

[8] Baldwin and Gorecki (1990) provide details on the creation of the data set.

[9] Corporations are assigned a country of control under CALURA based on the country of residence of the persons having the greatest potential to strategically influence the activities of the corporations.

[10] Small: 0 to 99 employees; medium: 100 to 499 employees; and large: 500+ employees.

[11] Grouping was done to reduce the errors in measurement that occur at the level of the individual establishment.

[12] Shipments were chosen because price indices for products that can be used for deflation are superior to those available for deflating value added. In addition, shifts in the composition of the Census Annual Survey of Manufactures that change the proportion of establishments reporting value added using the long form as opposed to the short form potentially cause some bias in value-added comparisons that are not corrected for these shifts.

[13] See Baldwin and Dhaliwal (2000) for a related study that estimates the marginal labour productivity from the same set of data used here. In the estimation of marginal labour productivity, selection effects are serious. They turned out not to be important for the results reported here. Generally, the cells with negative employment change are also those with negative output change. Nevertheless, we use the same categories here that were used in the earlier paper in order to provide comparability to the other paper.

Table 5.2 Effect of changes in employment and output on average labour productivity in the Canadian food and beverage sector, 1973-1993

Plant category	ΔLP_j Growing plants		ΔLP_j Contracting plants		ΔLP_j All plants	
(Control and size)	Mean	Standard error	Mean	Standard error	Mean	Standard error
Short run						
Canadian control						
– small	0.88	0.011	1.17	0.010	0.99	0.009
– medium	1.00	0.005	1.07	0.010	1.03	0.006
– large	1.02	0.010	1.05	0.019	1.03	0.009
Foreign control						
– small	0.93	0.018	1.10	0.014	0.99	0.012
– medium	1.02	0.012	1.07	0.014	1.04	0.011
– large	1.02	0.012	1.07	0.018	1.04	0.011
Long run						
Canadian control						
– small	0.91	0.021	1.29	0.016	1.06	0.023
– medium	1.08	0.016	1.15	0.015	1.10	0.014
– large	1.04	0.013	1.08	0.018	1.05	0.013
Foreign control						
– small	1.04	0.025	1.19	0.029	1.12	0.018
– medium	1.13	0.026	1.36	0.087	1.19	0.028
– large	1.15	0.045	1.23	0.042	1.18	0.035

The analysis is performed for both the short run and long run. The scope of this analysis is restricted to the food and beverage sector and the rest of the manufacturing industries; the latter combines the natural resources, labour intensive, scale-based, product-differentiated and science-based industries into one group.

The change in labour productivity (ΔLP_j) is expressed in ratio form. The formula is:

$$\Delta LP_j = LP_{t+j} / LP_t$$

where

LP_t = total shipments in period t divided by the total employment in period t,

LP_{t+j} = total shipments in period t+j divided by the total employment in period t+j,

t = the 1973-1992 period for the short run (annual) analysis or 1973-1988 period for the long run (five-year) analysis, and

j = 1 for the short run (annual) analysis or 5 for the long run (five-year) analysis.

ΔLP_j is calculated for growing, declining and all establishments together, and in each case by size and control. In each case, the shipment and employment data correspond to a particular group of establishments (defined in terms of sector, control and size). All shipments are measured in real terms by dividing the nominal values at the establishment level by the output price index of the corresponding four-digit (1980 SIC) industry.

ΔLP_j equals one when the marginal changes in output and employment do not alter labour productivity. For example, when scale economies are absent, the capital-to-labour ratio of the plant remains unchanged, or no efficiency improvements take place. When ΔLP_j is greater than one, labour productivity has improved as a result of the marginal changes in employment and output changes. For growing establishments, this happens when a given increment in employment is accompanied by a relatively larger expansion in output. This could occur when plants adopt advanced technologies or become more capital intensive. The presence of significant scale economies could also result in an improvement in the efficiency of all inputs, including labour. Finally, it could occur if employment expansion is concentrated in operations that bring the largest marginal gain in performance and profitability.

For the contracting segment of establishments, a gain in labour productivity ($\Delta LP_j > 1$) occurs when a contraction in output is accompanied by a relatively large contraction in employment. This could arise because the most inefficient operations are closed down first, or alternatively, the least productive members of the labour force are let go first. The gain in labour productivity for contracting plants could also occur as the result of a restructuring that boosts the capital-to-labour ratio.

Figure 5.5 Long-run growth in labour productivity in the food and beverage sector

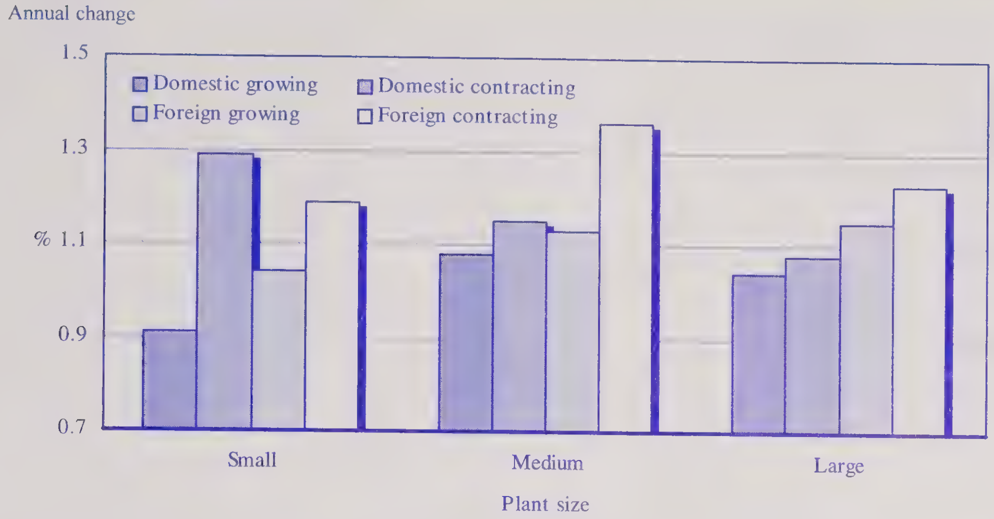


Figure 5.6 Long-run growth in labour productivity: Food and beverage versus all other manufacturing

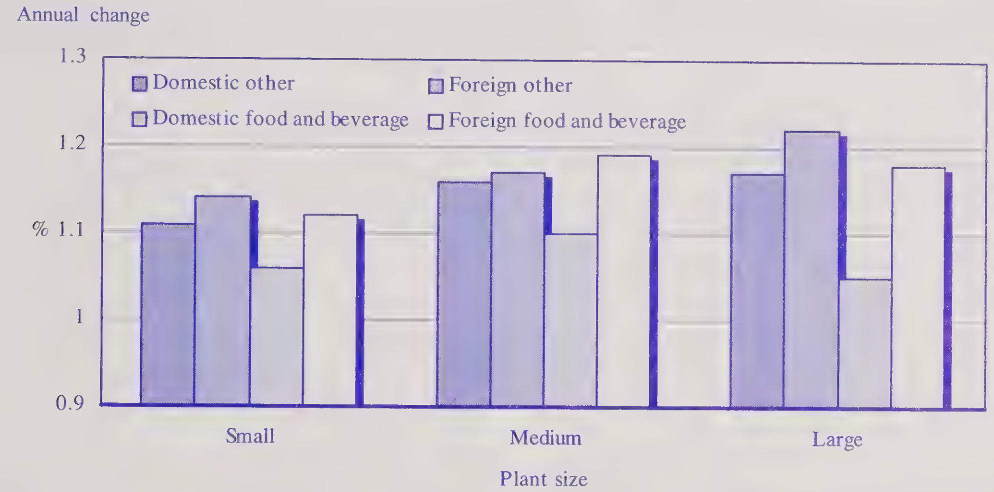


Figure 5.7 Long-run growth in labour productivity in all other manufacturing

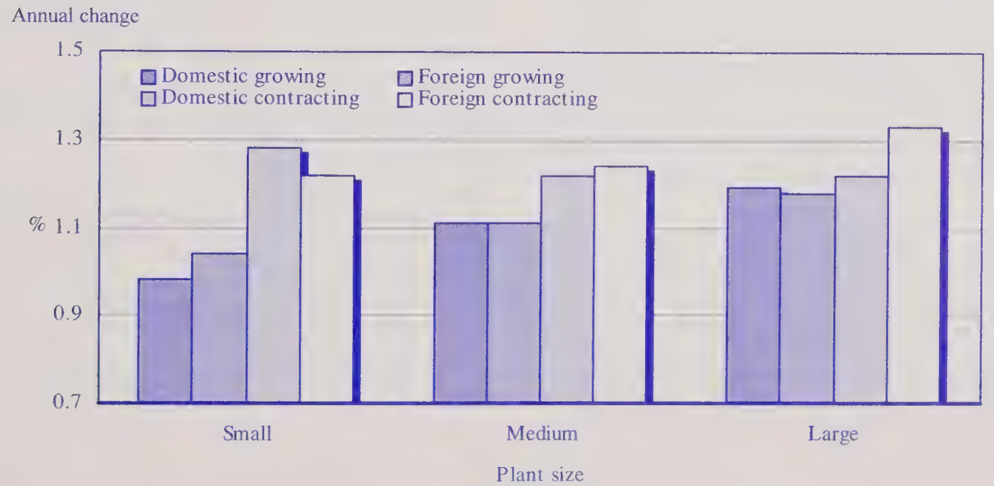


Table 5.3 Changes in labour productivity in the Canadian manufacturing sector excluding food and beverage industries, 1973-1993

Plant category	ΔLP_j Growing plants		ΔLP_j Contracting plants		ΔLP_j All plants	
(Control and size)	Mean	Standard error	Mean	Standard error	Mean	Standard error
Short-run						
Canadian control						
– small	0.91	0.006	1.17	0.008	1.01	0.005
– medium	1.01	0.006	1.08	0.009	1.04	0.006
– large	1.04	0.007	1.05	0.010	1.04	0.007
Foreign control						
– small	0.94	0.019	1.10	0.009	1.01	0.011
– medium	1.01	0.011	1.08	0.008	1.04	0.006
– large	1.02	0.010	1.09	0.017	1.05	0.007
Long-run						
Canadian control						
– small	0.98	0.009	1.28	0.014	1.11	0.008
– medium	1.11	0.013	1.22	0.024	1.16	0.011
– large	1.19	0.015	1.22	0.027	1.17	0.015
Foreign control						
– small	1.04	0.025	1.22	0.018	1.14	0.023
– medium	1.11	0.012	1.24	0.017	1.17	0.011
– large	1.18	0.024	1.33	0.040	1.22	0.020

A loss in or deterioration of labour productivity occurs when ΔLP_j is less than one. In the expansion phase, this could occur when mature or less efficient plants (either new entrants or firms that are in the early stages of the product cycle) are responsible for most of the expansion in output. In the contraction phase, it could happen if downsizing significantly reduces the efficiency of all production factors. Fixity of labour inputs could also cause labour productivity to decline when output falls.

Examining changes in productivity in both short and long run, by size class and by nationality of control reveals important information about differences in the growth process within the establishment population. The differences between the short and long run reveal the importance of input fixities, factor substitution, technology development and scale economies. The distinction by nationality of control (domestic versus foreign) captures the influence of firm-specific factors, such as technology, management, and other factor costs. Size differences allow us to understand the respective contribution of small versus large establishments.

Mean values of productivity gains and losses

The short- and long-run mean values of ΔLP_j (averaged over the sample period) for growing plants, contracting plants and all plants taken together—and in each case broken down by control and size—are reported in Table 5.2 for the food and beverage industries and Table 5.3 for the rest of the manufacturing sector.

Food and beverage sector

Generally, growing establishments have less increase in labour productivity than those contracting (Table 5.2). In the short run, the annual increase in the labour productivity for contracting plants ranged from 5% to 17%, while in the long run it was in the 8% to 36% range. In contrast, expanding plants in each category showed less of an increase in labour productivity and actually a decline in the smallest size class.

The net effect of growing and contracting plants on the overall labour productivity of the food and beverage sector reveals that the strong positive showing of establishments in the contraction phase outweighs their relatively weak or negative showing in the expansion phase. As a result, there was an overall improvement in labour productivity in almost all segments of the sector (Figure 5.6). The only exceptions are small plants where the marginal changes are almost productivity-neutral in the short run.

These differences in the growth and contraction categories capture disparities that arise because firms are at different stages in their life cycles and are being affected differently by macro-economic effects. The fact that these differences exist, whether we look at the short run or long run, suggests that the former outweigh the latter—that what we see here is primarily related to the life-cycle effect.

There are also substantial disparities across size classes, and these differences operate in different directions for

growing and contracting plants. For domestic growers, larger size classes increase productivity the most, and the smallest size classes, the least. The reverse is true for the contracting domestic class of plants. This difference comes primarily from the behaviour of the smallest size class—the class that contains most of the entry and exits of establishments that take place in the population. It is in this class that labour productivity falls for growing establishments and declining establishments have much higher labour productivity growth than both of the other two size classes. This peculiar result arises from the importance of entry and exit herein and the fact that new establishments initially are less productive than incumbent establishments and that most of the inefficient subsequently exit (see Baldwin and Rafiquzzaman 1995). The appearance of entrants in the smallest size classes drags down productivity therein and their demise has the opposite effect. On balance, however, their net effect (the 'All plants' column, Table 5.2) is neutral in the short run for the smallest classes. On the other hand, the larger size classes have a larger positive increase in the short run when both growing and contracting plants are averaged.

In the long run, some of the size-class effect is reduced as small establishments grow and improve their relative importance and as the largest size class reduces its performance, so that the two are about the same. The middle size class showed the largest improvements in labour productivity for domestic establishments.

The same gradations across size classes can also be discerned for foreign-controlled establishments. The net effect observed in the smallest size class is also essentially neutral in the short run, but it increases more in the long run for the foreign-controlled sector—but then it does so across all size classes. It is in the foreign sector that the largest differences occur across size classes. This occurs not so much because small establishments make little progress, but rather because the largest establishments have such large productivity increases.

Foreign establishments generally have higher rates of productivity increases. The domestically controlled establishments improved their overall labour productivity by about 3% in the short run and by between 5% and 10% in the long run. The gains are relatively higher at plants managed from abroad; they range from 4% in the short run to almost 18% in the long run. The one category where foreign-controlled labour productivity increases are not higher is for contracting plants in the smallest size class where exit effects are quite different. This is because foreign-controlled entrants tend to be relatively more productive and the same degree of churning owing to entry and exit does not occur in new foreign-controlled establishments.

The differences between domestic and foreign sectors are generally higher in the long than in the short run for each size class. This suggests that the differences that exist between the foreign and domestic sectors are difficult to see in the short run because of similar reactions to macro-economic fluctuations, but that over time growth tends to become more differentiated between the two groups.

Other manufacturing sector

For the rest of the manufacturing industries, the pattern of changes across both growing and contracting, small and large, and domestic and foreign-controlled groups are quite similar to those of the food and beverage sector discussed above.

First, larger plants experience greater increases in labour productivity than the smallest plants, which experience little change on balance (Figure 5.7). However, the size effect is more noticeable in the other manufacturing industries, in that the largest-size class experiences increases that are at least as large as the middle-size classes.

Second, foreign-controlled plants always perform better than domestic plants in the food and beverage sector. But the benefit of being controlled from abroad is slightly less in the rest of the manufacturing sector. For plants that expanded in the long run, the foreign-controlled small, medium and large plants led their Canadian counterparts by 13, 5 and 11 percentage points in the food and beverage industries and only 6, 0 and -1 percentage points in the rest of the manufacturing sector, respectively.

Finally, the net result of labour-output adjustment on labour productivity is always positive for all segments of the rest of the manufacturing sector and ranged from 1% to 5% in the short run and from 11% to 22% in the long run. These net gains are generally higher than those in the food and beverage industries (Figure 5.6).

Trends in the impact of size and nationality of control on labour productivity growth

Of critical interest is the extent to which the differences outlined in the previous section across size classes and nationality of control have changed.

During the period studied, Canada's economy became more open. Tariff rates fell and trade as a percentage of GDP increased. This may have allowed Canadian-controlled plants to increase their scale and improve their relative productivity. Yet, technological change has been rapid, and with the spread of new computer-based technologies (Baldwin and Sabourin 1995), foreign-controlled plants have been quicker to make use of these new technologies

Table 5.4 Impacts of size and control on changes in labour productivity, Canadian food and beverage sector

Explanatory variable	Short run			Long run		
	Growing plants	Contracting plants	All plants	Growing plants	Contracting plants	All plants
Intercept	0.94 (0.019)***	1.14 (0.024)***	1.024 (0.015)***	1.034 (0.036)***	1.25 (0.070)***	1.162 (0.031)***
Trend	-0.0055 (0.002)***	0.0003 (0.0022)	-0.0036 (0.0013)***	-0.0147 (0.004)***	-0.0078 (0.0079)	-0.017 (0.0035)***
S_2	0.0485 (0.023)**	-0.063 (0.0293)**	-0.0014 -0.0083	0.074 (0.045)*	-0.044 (0.0856)	-0.021 (0.038)
S_3	0.0543 (0.023)**	-0.092 (0.0293)***	-0.0057 (0.0083)	0.0003 (0.045)	-0.121 (0.0856)	-0.104 (0.038)***
CF	0.0013 (0.0185)	-0.038 (0.0239)	-0.0078 (0.015)	-0.038 (0.036)	-0.046 (0.070)	-0.031 (0.031)
S_2*Trend	0.0060 (0.0020)***	-0.0002 (0.0026)	0.0043 (0.002)***	0.0073 (0.005)	0.0077 (0.0097)	0.0104 (0.004)**
S_3*Trend	0.0067 (0.0020)***	0.0014 (0.0026)	0.0047 (0.002)***	0.0155 (0.005)***	0.0050 (0.0097)	0.0169 (0.004)***
CF*Trend	0.014 (0.002)	0.0023 (0.0022)	0.0017 (0.0013)	0.018 (0.004)***	0.0178 (0.0079)**	0.0167 (0.0035)***
R^2	0.53	0.20	0.20	0.48	0.11	0.43

Note: Three asterisks (***), two asterisks (**) and one asterisk (*) represents the significance of the coefficient at 99%, 95% and 90% levels, respectively.

(Baldwin and Diverty 1995; Baldwin and Sabourin 1997). It is, therefore, of considerable interest to know whether the productivity advantage of foreign establishments has been trending upward.

At the same time, the extent to which productivity differences have been changing across size classes is of interest since an increasing amount of employment is found in smaller establishments (Baldwin and Picot 1995). However, small establishments tend to be slow when adopting new technologies (Baldwin and Sabourin 1995; Baldwin and Diverty 1995) and the relative productivity of small establishments has fallen over the period (Baldwin 1998). The decline in relative productivity, combined with the increasing share of employment in this group, has accounted for part of the productivity slowdown experienced by the Canadian manufacturing sector (Baldwin 1996).

Investigating whether this decline is simply the result of the increasing importance of small domestic plants or whether it is the result of peculiarities of specific subsectors requires that changes in labour productivity be tracked over time and compared across size classes, industry and nationality of control.

To do so, we tested whether changes in labour productivity exhibited any time trend, and whether these trends are statistically different by nationality of control and by size class. We employed the following regressions on the time series data used to construct the mean values given in Tables 5.2 and 5.3.[14] The length of time is 1973-1992 for the annual growth and 1973-1988 for the five-year growth. The regression used was

$$\Delta LP_j = f(S_2, S_3, CF, \text{Trend}, S_2{*}\text{Trend}, S_3{*}\text{Trend}, CF{*}\text{Trend})^{15}$$

where Trend is a variable taking values from 0 to 19 for the annual changes and from 0 to 15 for the five-year changes; S_2 and S_3 are binary variables for medium and large size plants, and nationality (CF) is a binary variable

[14] The pooled regression corrected for first-order serial correlation, contemporary correlation across categories, and heteroscedasticity.
[15] We also experimented with interaction terms between the size variables and the foreign-control variable. This did not affect our results in any meaningful fashion.

Table 5.5 Impacts of size and control on trends in labour productivity, Canadian manufacturing sector excluding food and beverage industries

Explanatory variable	Short run			Long run		
	Growing plants	Contracting plants	All plants	Growing plants	Contracting plants	All plants
Intercept	0.962 (0.017)***	1.12 (0.017)***	1.017 (0.011)***	1.04 (0.027)***	1.231 (0.039)***	1.136 (0.024)***
Trend	-0.0039 (0.0016)**	0.0024 (0.0015)	-0.0007 (0.0010)	-0.0067 (0.0031)**	0.0008 (0.0044)	-0.0035 (0.0027)
S_2	0.0037 (0.021)*	-0.067 (0.021)***	0.0039 (0.013)	0.051 (0.033)	-0.068 (0.0473)	-0.0038 (0.029)
S_3	0.046 (0.021)**	-0.095 (0.0207)***	0.0017 (0.013)	0.085 (0.033)**	-0.1045 (0.0473)**	-0.032 (0.0289)
CF	-0.013 (0.017)	-0.0154 (0.069)	-0.0067 (0.0110)	-0.044 (0.027)	0.0301 (0.0386)	0.0067 (0.0236)
S_2*Trend	0.005 (0.0019)***	0.0014 (0.0019)	0.0029 (0.0012)**	0.0066 (0.0037)*	0.0060 (0.0054)	0.0057 (0.0038)
S_3*Trend	0.007 (0.0019)***	0.0033 (0.0019)*	-0.0035 (0.0012)***	0.0121 (0.0037)***	0.0170 (0.0054)***	0.0140 (0.003)***
CF*Trend	0.0013 (0.0015)	-0.0003 (0.0015)	0.0008 (0.0009)	0.0082 (0.0031)***	-0.0007 (0.0044)	0.0052 (0.003)*
R^2	0.16	0.10	0.08	0.20	0.04	0.12

Note: Three asterisks (***), two asterisks (**) and one asterisk (*) represents the significance of the coefficient at 99%, 95% and 90% levels, respectively.

for foreign-controlled plants. The results for the food and beverage industries are presented in Table 5.4 and for the rest of the manufacturing sector in Table 5.5. Below we discuss results for the long-run analysis only. We further restrict our discussion by comparing the results for small and large size plants since the performance of the medium size plants generally falls between the two polar categories.

Food and beverage sector

In the previous section, we showed that large growing plants had a significant edge over their small counterparts in terms of the effect of marginal changes on labour productivity; on average, it was 14 and 9 percentage points for Canadian and foreign-controlled plants, respectively. The regression results presented in Table 5.4 show that the gap between the two rates of change widens over time (the negative coefficient on TREND, which captures the trend in small plants and the positive coefficient for S_3*TREND representing large plants).

For contracting plants, productivity improvements were larger for small plants than for large plants. The difference between the two was 12 percentage points for the Canadian plants and 3 percentage points for the foreign-controlled plants, thereby indicating that this phenomenon was being driven primarily by the domestic sector. This gap in labour productivity gain is stable over time—all coefficients involving TREND are insignificant in both the short and long run.

The net effect of growing and contracting plants is reflected in the coefficients in the all-plants regression. Here, the gap between small and large plants gets larger over time in that the trend variable (representing the small sector) has a significantly negative coefficient and that the TREND variables for the middle- and largest-size classes are positive and significant. This result is largely being driven by the size-class differences in the growing sector.

The difference between domestic and foreign-controlled plants at the beginning of the period was not statistically significant (the coefficient on CF is insignificant). However, the difference between the two increases over time (the coefficient on CF*TREND is positive and significant everywhere). Thus, the effect of foreign control on the rate of increase in labour productivity has grown larger over the period studied here.

Manufacturing sector excluding food and beverage sector

The results for the rest of the manufacturing sector are very similar to those for the food and beverage sector discussed above. In both cases, small growing establishments are less productive than their large counterparts and the trend over time increases the difference. Differences occur between food processing and the rest of the manufacturing sector in downsizing plants. Large plants in the more aggregated sector tend to become more and more successful downsizers over time whereas this effect is not significant in food and beverage. The coefficient on S_3*TREND is positive and significant in the rest of the manufacturing sector whereas it is positive but insignificant for food and beverage.

Although the results of Table 5.5 aggregate sectors together, we also examined the trend at each of the sectoral levels—for natural resources, scale-based, labour-intensive, product differentiated and science-based industries. The trend variable for the largest-size class is positive and significant for all but the labour intensive sector. The size effects that have been reported are found across a wide range of industries.

As in the food and beverage sector, the gap between foreign-controlled and domestic establishments in the rest of the manufacturing sector increased over time (as indicated by the positive and significant coefficient on CF*TREND in Table 5.5). While this trend is not evident in the contracting sector, it is found in the all-plants equation. However, the effect of foreign control is stronger, more significant, and more widely spread across both growing and contracting plants in the case of the food and beverage industries than for other sectors. Elsewhere, this nationality effect is strongest and most significant in the scale-based, the product differentiated, and the natural resources sectors.

5.6 Conclusion

If we are to study employment growth and how firms are responding to output changes, we must be cognizant of the extent of heterogeneity in the population. That is the reason we have divided the population here into establishments that are increasing their demand for labour and those that are contracting their labour force.

There are substantial differences in the pattern of labour productivity increases across these two groups of plants. Labour productivity has increased more over time for contracting plants than for growing plants, for large as opposed to small plants and for foreign as opposed to domestic plants. Restructuring that has seen the decline (in terms of share of employment) of large plants and a decline in the importance of foreign-controlled plants (in terms of share of employment) would have slowed productivity growth.

It is noteworthy that it is not only a shift in share of employment from one group to another that has caused this decline. The differences between small and large establishments and domestic and foreign plants have increased over the period of the study. Whether this is caused by a change in technology or in capital intensity, or is ascribed to some other factor, cannot be ascertained from this study. We do know that these groups differ in terms of their application of advanced computer based technologies. We also know that variables like average wage rates have been increasing in those plants that employ these technologies relative to those that do not (Baldwin, Gray and Johnson 1996a; Baldwin and Rafiquzzaman 1998). The changes in labour productivity may reflect these technological differences.

It is also evident that these changes take place slowly. The trends in relative labour productivity, whether in terms of differences across size-classes or differences across nationality groups, have developed slowly, but there is little doubt about the direction of the trend.

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6 The Structure of Investment in Canada and its Impact on Capital Accumulation

John R. Baldwin and Tarek M. Harchaoui

6.1 Introduction

From an average of 24% of GDP in the 1960s and 1970s, gross savings in Canada fell to roughly 18% in the 1990s.[1] This decline has been a source of concern to some as it affects the investment-to-GDP ratio, and investment is seen to hold the key to productivity growth. A concomitant slowdown in Canadian productivity since 1973 has supported these concerns. They have been reinforced by international comparisons that typically show Canada towards the bottom in terms of both its national savings rate and its productivity growth rate (Bosworth 1990; Edwards 1995).

This chapter investigates three issues related to investment spending since the early 1960s.

- First, how does the decline in the Canadian savings rate relate to investment spending in different areas? Has it primarily affected machinery, structures, housing, or government investment?

- Second, has the reduction in savings resulted in a dramatic change in the sources of financing on which investment relies? Here we ask whether financial constraints are related to the historically low level of the business sector's investment-to-output ratio during the recent expansion period.

- Third, has the reduced level of investment affected the Canadian economy's long-run trend to increase the amount of capital available per worker? Was investment sufficient to augment the capital-to-labour ratio during the recent decades?

Section 6.2, which examines patterns of savings and investment for the 1961-1999 period, shows that the impact of declining national savings on Canada's business investment has been cushioned, because decreases in housing and government investment absorbed a substantial part of the decrease in spending. Moreover, the cutbacks that have occurred in business investment have been concentrated in structures, not equipment.

Section 6.3 investigates access to finance and asks whether there is evidence that restrictions on savings have led the business community to turn to new sources of funds. It finds that internal funds have been more than enough to finance fixed investment in recent years.

Section 6.4 examines the impact of changes in the structure of investment on the amount of capital available per worker. While the capital-to-labour ratio for most industries experienced rapid growth in recent years, the overall capital stock per worker grew at a somewhat slower pace than in the past. The relatively modest increase in the capital-to-labour ratio of the business sector is not the result of a restructuring away from goods to services.

6.2 Patterns of investment in Canada

Analysis at the aggregate level

In the Canadian System of National Accounts, savings, by definition, equals investment. A decline in savings as a percentage of GDP necessarily translates into a decline in investment.

[1] Gross saving is defined as the sum of saving and capital consumption allowances. See Statistics Canada (1998). The data used in this chapter came from various sources published by Statistics Canada. The investment series are from the Income and Expenditure Accounts Division and the Input Output Division; the financial statistics are from the Income and Expenditure Accounts Division; the labour data are from the Micro-economic Analysis Division; the capital stock series are from the Investment and Capital Stock Division. The U.S. data on investment are published by the Bureau of Economic Analysis.

Figure 6.1 Gross investment, share of GDP (in current prices)

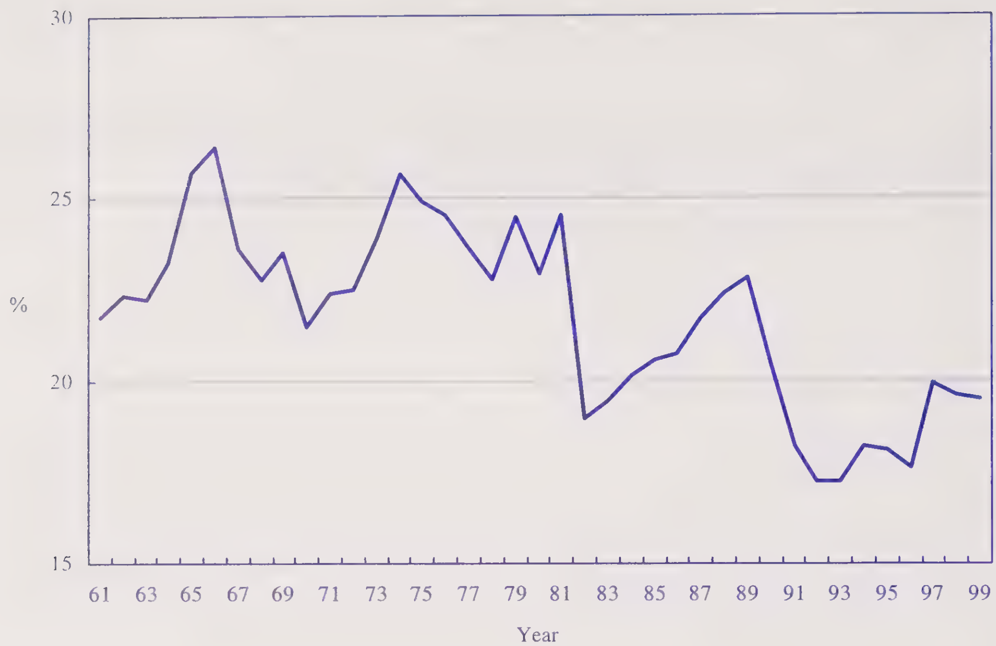
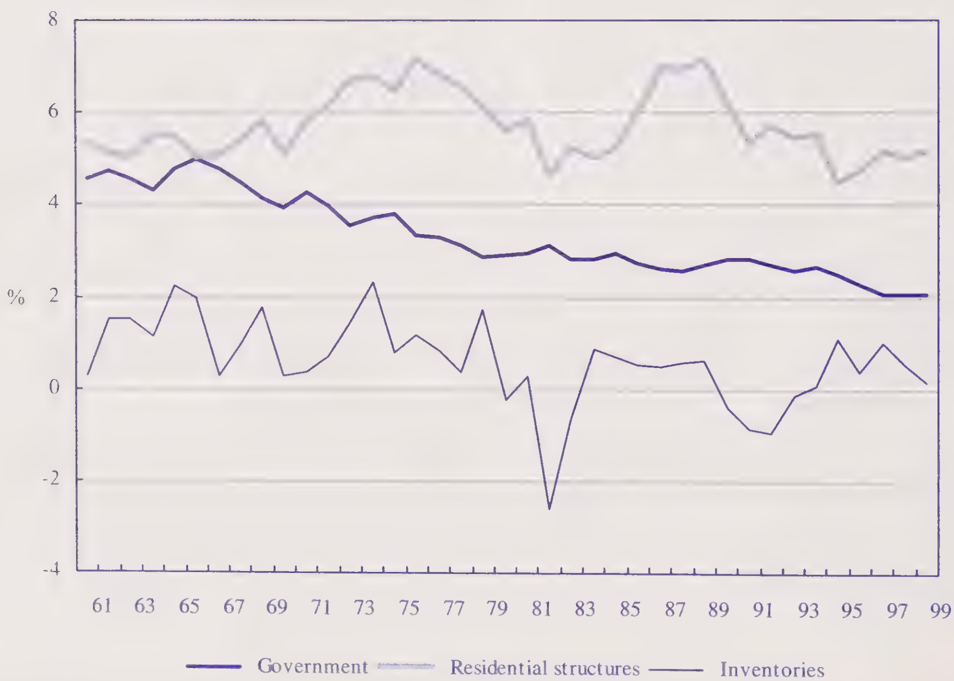


Figure 6.2 Gross investment by component, share of GDP (in current prices)



In this chapter, we start by examining the course of the ratio of investment to output over time. These ratios tell us whether the amount of total GDP devoted to investment is being held constant over time. It is also of interest to examine the growth in real capital stock or in real capital per worker, but these are topics that are addressed elsewhere and at the end of this chapter.

We start by using ratios calculated in nominal dollars, rather than ratios calculated in real dollars because the latter inherently do not make sense for our purpose (see also Ehemann, Katz and Moulton, 2000; Whelan, 2000). They do not make sense because we are interested in asking how much of today's resources are being devoted to investment and how that compares to previous years. A real ratio that uses a set of base prices from a previous period compares the expenditures on investment using a previous set of prices and essentially tell us whether holding prices constant, we would be increasing or decreasing the percentage of total expenditures to investment. However, we are not interested in whether we could spend considerably less on investment if we had to pay for the investment using prices in a prevous period. We are asking what percentage of the resources presently available are devoted to investment—and for that we need to use current price ratios throughout.

There are other more practical reasons to avoid ratios of investment to GDP using real ratios. First, price deflators for machinery and equipment are probably less precise than those for consumption. Secondly, we are interested in cross-country comparisons of investment of GDP and the price indices used in different countries are not always calculated the same way. For example, Canada uses a Paasche price index and the U.S. derives a Fisher price index. In periods of rapid technological change, these indices will be quite different.

Investment is made up of a number of components. Investment includes not only the business expenditures on equipment and non-residential structures that are the focus of most concerns about output and productivity growth, but also residential investment, government investment and business inventories.

The overall investment rate averaged 23.5% of GDP from 1961 to 1969, but it fell to 18.6% between 1990 and 1999 (Figure 6.1). Reductions in the fraction of GDP devoted to investment in housing, government structures and equipment, inventories, and non-residential structures have been the primary effects of declining savings. The share devoted to residential housing was relatively constant, averaging 5.3% of GDP at the beginning and end of the period (Figure 6.2). However, government investment fell from 4.6% to 2.4% of GDP, and non-residential structures fell from 6.1% to 4.7% of GDP (Figure 6.3). Equipment investment only fell from 6.2% to 6.1% of GDP.

There have been fluctuations over time in the importance of these various categories—especially in residential and non-residential structures. Residential investment (Figure 6.2) has gone through several long cycles, peaking in the mid-70s and again in the late 1980s. It suffered a long recession during the early 1980s and a similar fate in the 1990s.

Housing does not directly contribute to estimates of productivity growth in the business sector because investment in housing, unlike business investment, is not a vehicle for introducing new technologies into businesses. However, the decline in housing investments to GDP could have an effect on the amount of housing stock available to serve a growing population.

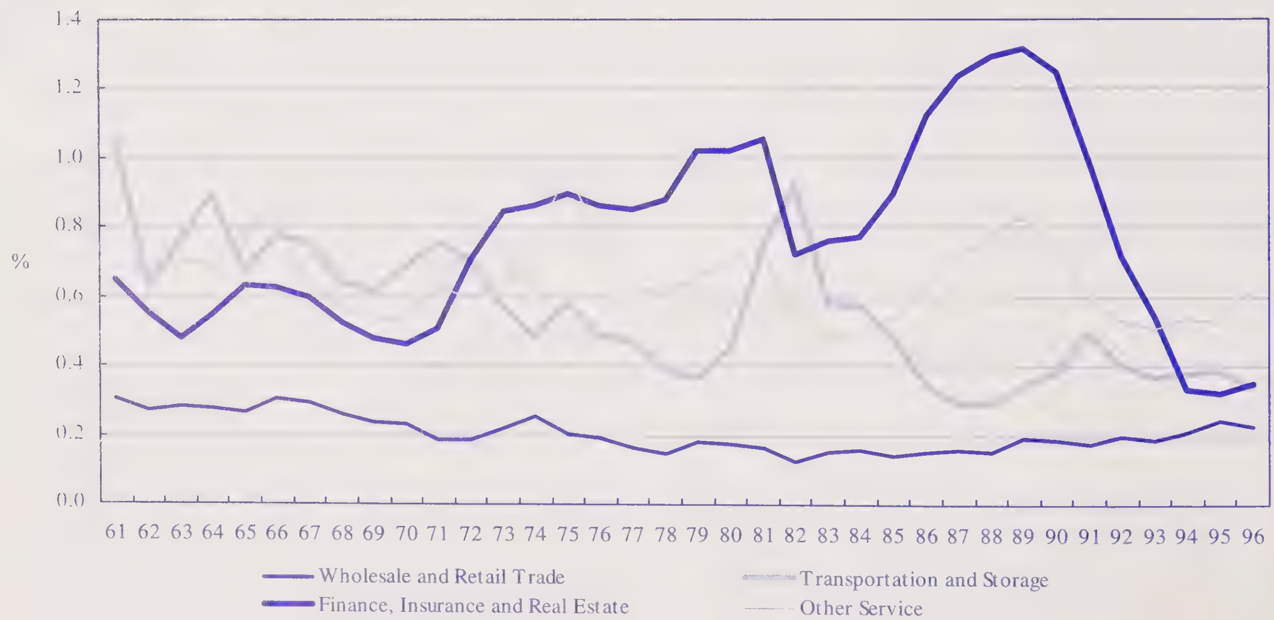
Inventory investment is also volatile. Substantial disinvestment (i.e., negative changes) in inventory occurred in each of the two recessions of the early 1980s and early 1990s. Inventory investment as a percentage of GDP has trended downward over time—averaging around 1% of GDP in the 1960s but less than a tenth of that in the 1990s. This decline in inventory investment relative to GDP is the result of improved inventory management techniques that have enabled businesses to reduce their inventory holding costs.

The consequence of the decline in government investment has been the subject of a considerable debate in academic circles, especially in the United States. Several studies have argued that declining rates of public capital investment precipitated the decline in U.S. productivity growth.[2] However, other studies, using somewhat different measures of public capital, have found its impact on various measures of economic activity to be quite small. Most of the discussions about the role of public investment have focused on highways and other state and local government investments. But state and local investment accounts for only a portion of the decline. More important has been the declining fraction of GDP devoted to national defence. During the 1970s, the federal government made substantial purchases of aircraft, ships and other defence equipment. Investment in national defence picked up again in the mid-1980s, but it has subsequently fallen again relative to GDP.

[2] See Harchaoui (1997) on the contribution of public capital to productivity growth of Canadian industries.

Figure 6.3 Gross investment by component, share of GDP (in current prices)

Figure 6.4 Gross investment in structures, selected industries, share of GDP (in current prices)



Regardless of their views on the decline in government investment, most advocates of higher savings and investment are concerned with business investment. The latter displays a highly variable pattern—with little long-run trend. The share of GDP going to business investment in equipment saw peaks in 1966, 1975, 1981 and 1989 (Figure 6.3). These peaks also broadly correspond to the cycles in non-residential structures. Recently, however, trends in these two components have diverged, with investment in structures trending downward while the share of GDP going to business equipment has begun to recover.

Pattern of the investment components

Investment in construction as well as machinery and equipment constitute the two components of business investment in Canada through which new technologies are introduced to the economy. Of these two, the non-residential structures component has fallen quite sharply as a percentage of GDP from comparatively high levels in the late 1970s.

This movement has been partially driven by a decline in commercial office construction, mainly in the finance, insurance and real estate sector.[3] From an average of 0.79% of GDP in the 1970s, this component increased to 1.0% in the 1980s and then declined to 0.63% in the 1990s. Vacancy rates soared in the early 1980s and 1990s, precipitating a commercial real estate 'bust' and a sharp curtailment in office construction (Figure 6.4).

Investment in mining construction (Figure 6.5) has also followed a pronounced 'boom and bust' pattern. Investment surged following the second oil price shock in 1979, increasing from 1.5% in the 1970s to over 1.9% of GDP in the 1980s. It then plummeted to 1.4% in the 1990s when real energy prices continued to decrease.

Energy-related utility investments (Figure 6.5) have also fallen to annual rates (0.77% in the 1990s) that are only half those in the 1970s (1.4%). This shrinkage in energy-related investment has occurred in the context of a decline in the real price of energy and a slowing in the growth of energy use.

Investment in railroad construction and other transportation infrastructures (relative to GDP) has fallen (Figure 6.4). In the 1960s, transportation investment was 0.8% of GDP while in the 1990s, it was only 0.4%.

Business machinery and equipment, the largest of the major components of investment, follows a different trend than the structures that are associated with the expansion of businesses. The fraction of GDP devoted to business equipment (Figure 6.3) rose on average from 6.2% in the 1960s to 6.5% in the 1970s and 1980s and then declined marginally to 6.1% in the 1990s.

While there has been a general absence of a trend for all components of machinery and equipment, it nevertheless has followed a highly cyclical pattern over the whole period.

The bulge in business equipment investment in the late 1970s reflected a confluence of forces—a cyclical peak that arose from a rising trend for investment in machinery and equipment, particularly agricultural machinery and oil field equipment, in response to rapidly rising food and energy prices.

The recession of the early 1980s produced a sharp fall-off in the more cyclical components of investment in manufacturing industries such as electrical, electronic and communication equipment, and motor vehicles, other transportation equipment and parts (Figures 6.6 and 6.7). At the same time, more moderate growth in agricultural prices created financial pressures for farmers, many of whom had expanded in the previous decade.

Investment in the machinery and equipment component, although hard hit by the recession of the early 1980s, slightly increased in the late 1980s (Figure 6.6). The recession of the 1990s brought business investment's share of GDP to its lowest level for the 1961-1996 period. Since then, investment in business equipment has picked up and has exhibited the highest average annual growth rate of all past expansion periods (1966-1981 and 1982-1988). Nevertheless, as of 1996, business investment in machinery and equipment as a share of GDP remained below the highs reached in the early 1980s.

Turning to the industry distribution of machinery and equipment expenditures (Figures 6.8 and 6.9), several long-run structural changes are evident over the whole period. Other service industries, which include business services and communications, have expanded their share over most of the period (Figure 6.8). Although they experienced a distinct decline in share in the 1980s recession, they regained their 1970s share by the late 1980s and have more or less maintained it into the 1990s. Finance, insurance and real estate have also expanded their share over time, especially in the late 1980s and late 1990s. Wholesale and retail trade also expanded their share of investment.

[3] Even though this sector accounts for a modest 14% on average over the 1961-1996 period.

Figure 6.5 Gross investment in structures, selected industries, share of GDP (in current prices)

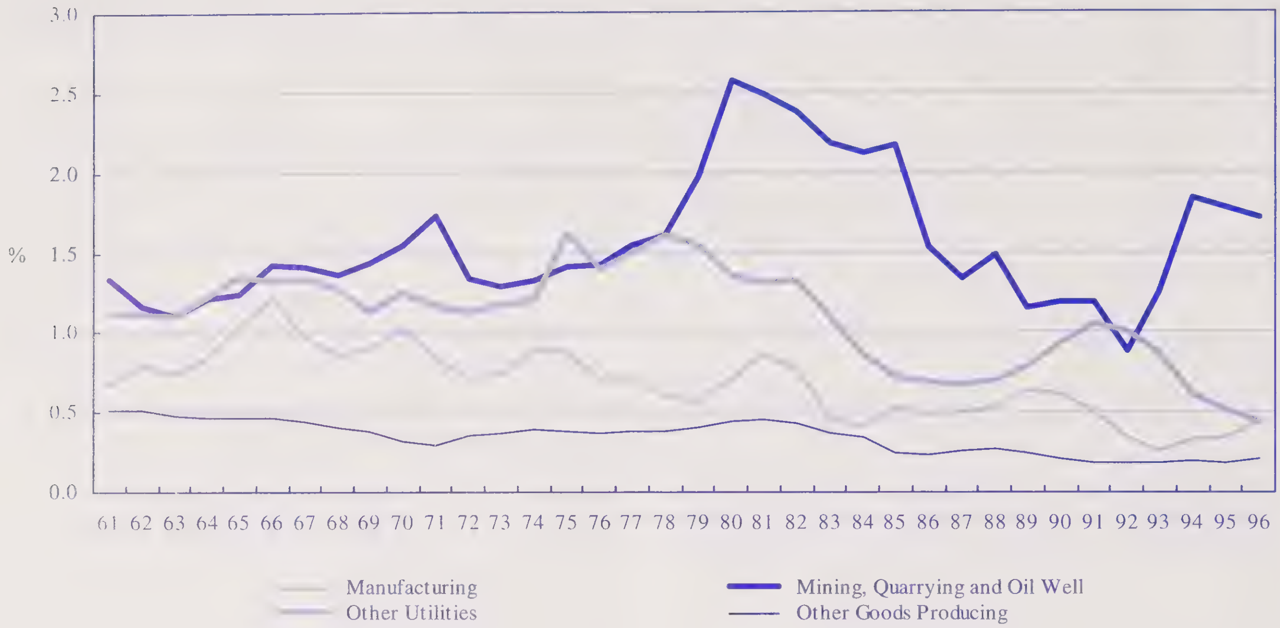


Figure 6.6 Gross investment in machinery and equipment by asset type, share of GDP (in current prices)

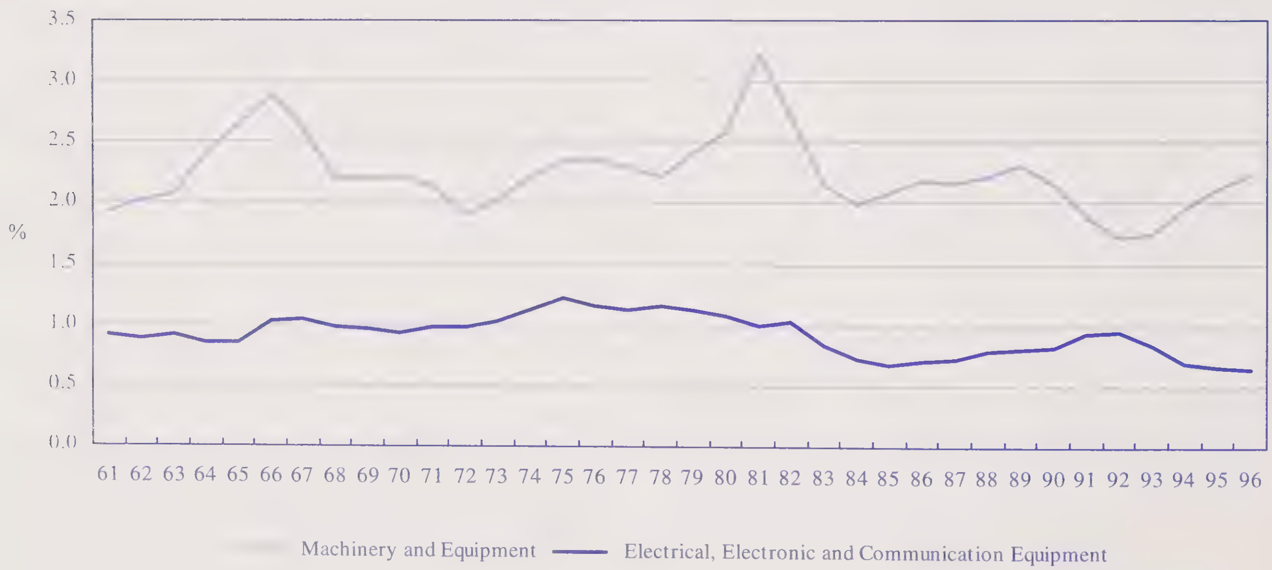


Figure 6.7 Gross investment in machinery and equipment by asset type, share of GDP (in current prices)

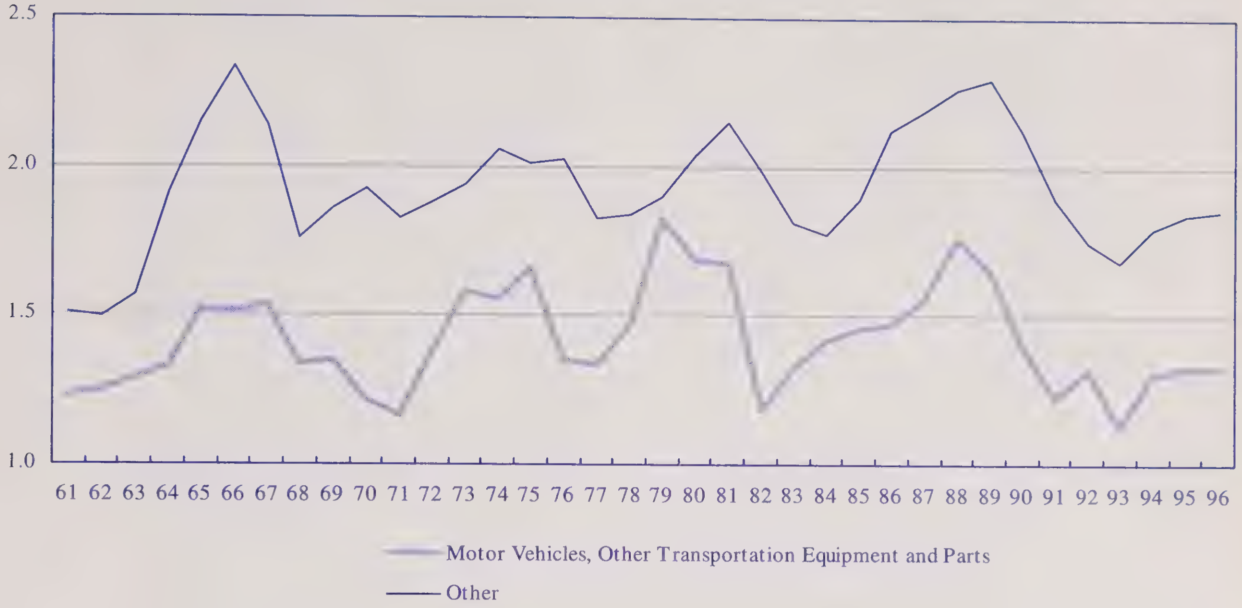


Figure 6.8 Gross investment in machinery and equipment, selected industries, share of GDP (current prices)

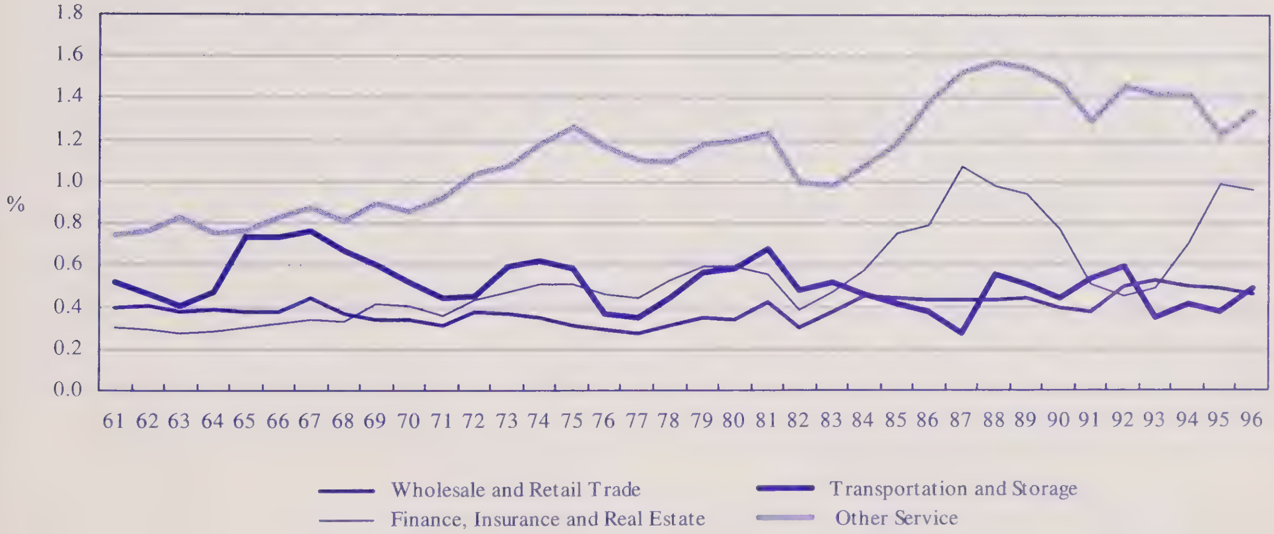


Figure 6.9 Gross investment in machinery and equipment, selected industries, share of GDP (current prices)

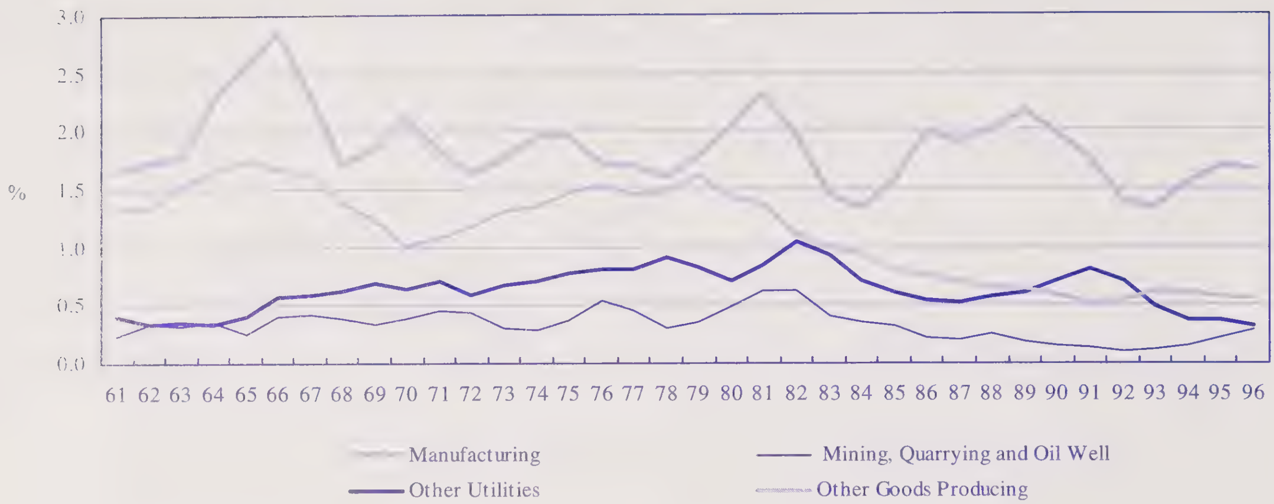


Figure 6.10 Gross investment, share of GDP, United States (in current prices)

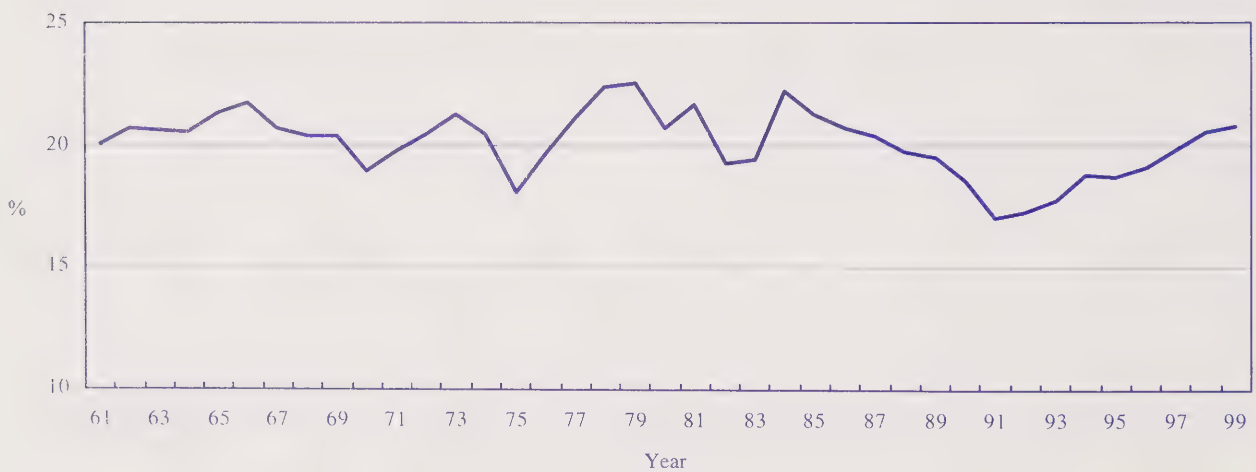


Table 6.1 Canadian and U.S. investment intensity, 1960-1999

	Canada	United States	Difference
		% investment divided by GDP	
Machinery and equipment			
1960–69	6.18	6.13	0.05
1970–79	6.45	7.18	–0.73
1980–89	6.54	7.78	–1.24
1990–99	6.13	8.20	–2.07
Residential structures			
1960–69	5.32	4.64	0.68
1970–79	6.37	4.94	1.43
1980–89	5.87	4.34	1.53
1990–99	5.28	3.88	1.40
Non-residential structures			
1960–69	6.14	3.71	2.43
1970–79	6.21	3.90	2.32
1980–89	6.13	4.35	1.78
1990–99	4.66	2.94	1.72
Government			
1960–69	4.59	5.21	–0.62
1970–79	3.58	3.71	–0.12
1980–89	2.82	3.63	–0.81
1990–99	2.45	3.33	–0.88
Total			
1960–69	22.22	19.68	2.54
1970–79	22.63	19.73	2.91
1980–89	21.37	20.09	1.28
1990–99	18.52	18.35	0.17

Note: The total includes only the following categories: residential; non-residential; machinery and equipment; and government. Inventories are excluded.

The utilities industry experienced an expansion phase in the 1970s and then a gradual decline afterwards. Transportation industries also followed much the same pattern, with an expansion in the late 1960s and early 1970s and then a gradual retrenchment thereafter.

The other goods industries (agriculture, forestry and fishing) decreased their share of investment. This decline was particularly marked after the 1980s recession, which was also the case for the mining industry.

Finally, manufacturing experienced a major investment boom in the late 1960s but then varied around a mean that did not change until the 1990s, when it declined slightly.

In summary, the historical pattern of investment in Canada indicates that the declining savings rate was primarily reflected in reductions in the share of GDP devoted to investment in non-residential structures and government. The proportion of GDP devoted to machinery and equipment remained roughly constant between the 1960s and the 1990s, with a peak in the early 1980s followed by a sharp drop back to previous levels. The record high of the ratio of investment in equipment to GDP experienced in the early 1980s coincided with transitory effects in the supply of agricultural products and oil. Oil-related investment alone accounted for half of the decline in business investment's share of GDP since the early 1980s. Similarly, a decline in investment in agricultural machinery also occurred when the rate of increase in agricultural prices slowed.

The Canadian experience in terms of the decline in the savings rate, its impact on investment rate, and the change in the composition of investment has both similarities and differences to the United States. Gross investment as a share of GDP in the United States has remained relatively constant over the past 20 years (Figure 6.10). Declines have occurred in residential structures and government investment in defence equipment but not in business capital expenditures in equipment (Figure 6.11). The change in the composition of U.S. business investment mirrors the Canadian experience. Cutbacks that have occurred in business investment in the United States have been concentrated in non-residential structures not equipment (Figure 6.12).

Figure 6.11 Components of gross investment, share of GDP, United States (in current prices)

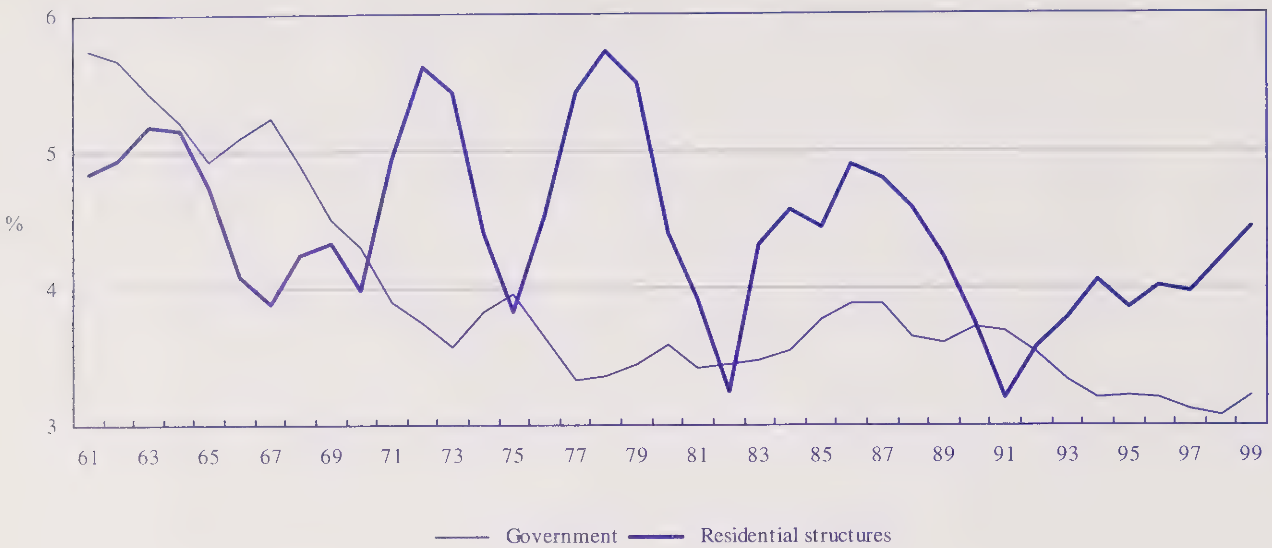
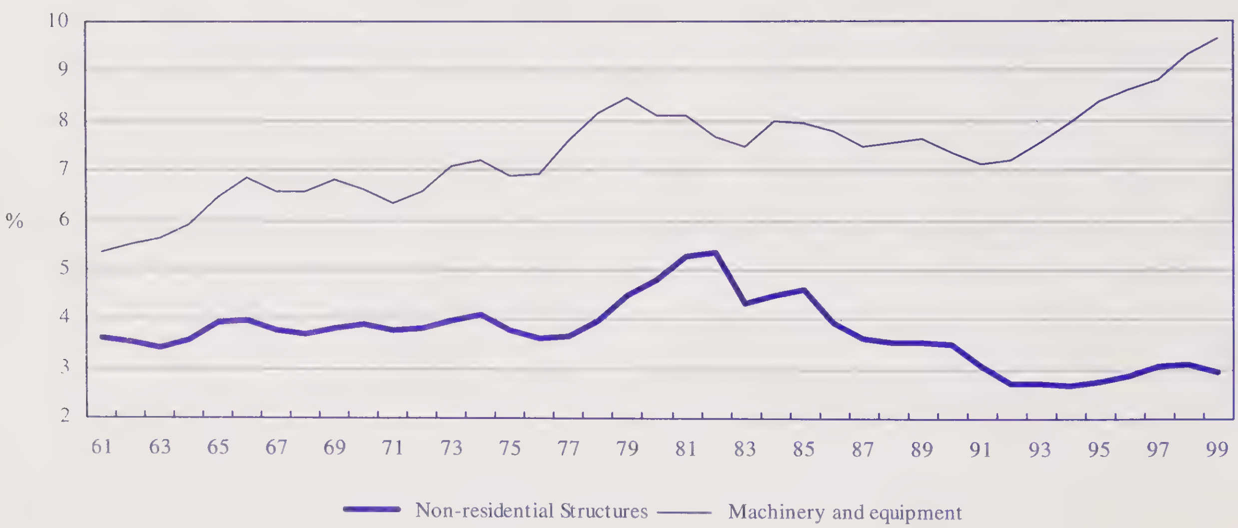


Figure 6.12 Components of gross investment, share of GDP, United States (in current prices)



Particularly pronounced were the reductions in spending on oil and gas exploration and development starting in the early 1980s and in expenditures on office buildings in the latter part of that decade. The sources explaining this drop are identical in both the United States and Canada—the collapse of oil prices and the high vacancy rates that emerged in many office markets.

The changes in investment intensity in Canada and the United States are compared in Table 6.1. Canada has consistently invested more (relative to GDP) than has the United States in residential housing. Since the 1970s, both countries decreased the proportion going to this area by about the same amount.

Canada has also spent more on structures, but the difference has been reduced. It was 2.4% in the 1960s, but only about 1.7% by the 1990s.

In contrast, the United States has consistently invested more in the government sector, but again both countries have reduced the amount spent relative to GDP by about the same amount.

A major difference between Canada and the United States occurs in machinery and equipment spending. The ratio of investment in machinery and equipment-to-GDP increased steadily in the United States from 6.1% of GDP in the 1960s to a record high of 8.2% in the 1990s. In contrast, the Canadian percentage of investment in machinery and equipment has remained relatively constant. By the 1990s, Canada was spending about 2 percentage points less of GDP on machinery and equipment than the United States.

In Canada, the fraction of GDP devoted to business equipment, which increased slightly between 1961 and 1999, has never significantly outperformed the contribution of residential and non-residential structures to GDP. The opposite is the case in the United States.

6.3 The financial structure of aggregate investment

In this section, we ask whether there have been changes in the patterns of financing that have accompanied shifts in the investment-to-GDP ratio. Changing patterns of financing may reveal that problems have arisen that have led to more expensive or less flexible sources of financing.

The corporate sector, which was responsible for 62% of investment in structures and equipment in 1997, financed its investment activities through a combination of funds generated internally and acquired from external sources.

The corporate sector can invest the funds that it raises in financial assets (investments in consumer or government debt) or non-financial assets (fixed investments such as plant and equipment). In other words,

Internal Funds + External Funds = Investments in Structures and Equipment + Inventories + Financial Assets

Funds generated internally consist of depreciation and undistributed profits (or profits less taxes and dividends). Of the two sources of internal funds, depreciation is by far the larger (69% over the 1961-1999 period).

Internal funds are much more important than funds raised from external sources. Figure 6.13 illustrates that corporations' funds generated internally, in the aggregate, generally approach their fixed investment expenditures. In the two recessions of the early 1980s and 1990s, funds generated internally fell very much short of fixed investments.

In the mid-1990s, funds generated internally moved back well above fixed investments. While individual corporations may make extensive use of external funds, the corporate sector's fixed investment expenditures can be said to be self-financing, since corporate savings in the form of undistributed profits and depreciation are roughly equal to corporate investment in plant and equipment.

At the same time as the corporate sector raises internal sources of financing, it also raises funds from external sources to finance investment in financial and non-financial assets. Financial assets consist of the obligations of others, such as foreign investments, credit granted to customers or government liabilities.

The reliance on external sources of financing has varied significantly since the early 1980s. In particular, use of credit markets (equity, corporate bonds, bank loans and mortgages) reached a high of 95% of fixed investment in 1981 and then dramatically declined to 15% in 1983. As one might expect, the corporate sector looked to markets more when funds generated internally did not keep pace with the growth in investment in the late 1970s and the late 1980s; and they curtailed their use of credit markets when internal funds rose relative to investment, as happened in the early 1980s.

The relative importance of the instruments used to raise external funds (credit market borrowing versus net equity issues) has varied considerably (Figure 6.14). During the early 1970s, when the corporate sector borrowed aggressively from credit markets to fund its investment programs, its reliance on the stock market was relatively low. The

Figure 6.13 Source of investment funds relative to fixed investment for non-financial corporations

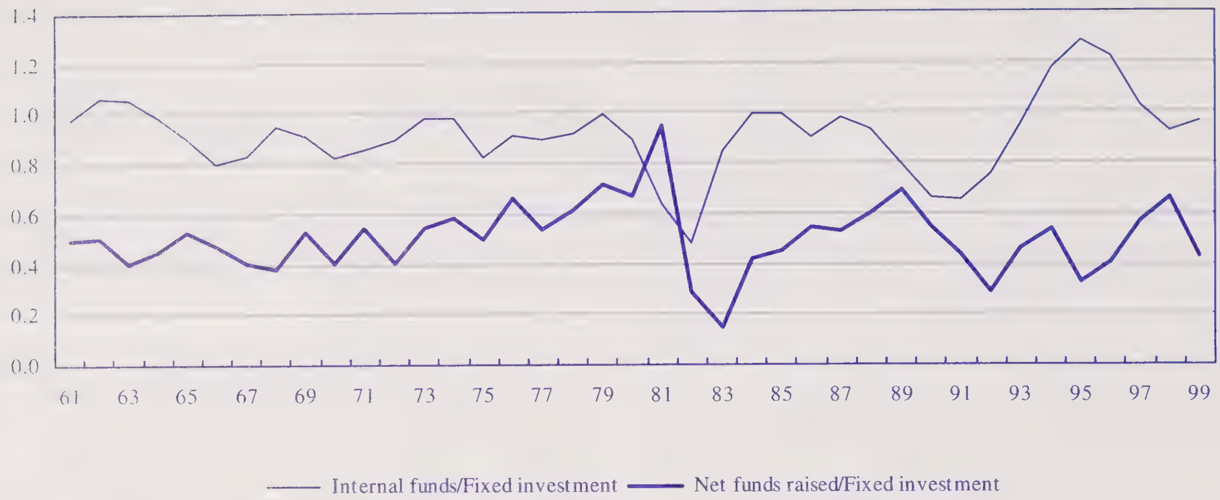
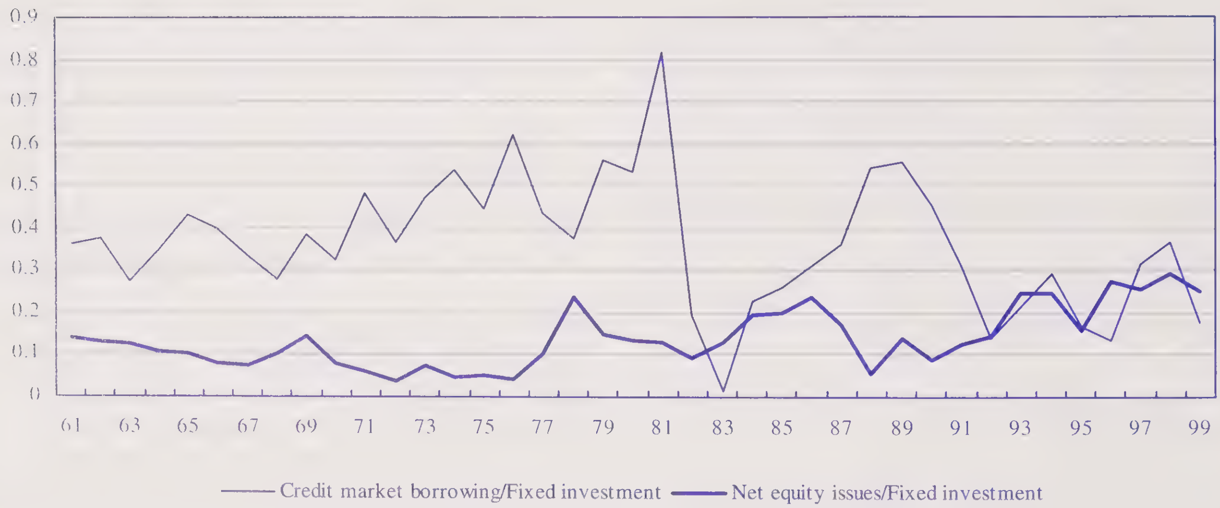


Figure 6.14 Source of investment funds relative to fixed investment for non-financial corporations



late 1980s was a time of increasing leverage, as corporations took on more debt while extinguishing equity through stock buybacks and mergers. In the recession of the early 1990s, borrowing from banks and other mortgage lenders declined while corporations continued to issue equities. During the recession, the equity and credit markets had about the same importance in financing investment. In the late 1990s, the corporate sector did not increase its use of credit markets, perhaps because of the record growth in internal funds.

Finally, we ask whether the changes in financing previously described led to dramatic shifts in the importance of each of the sources of funds to the business sector's balance sheets. For this we plot the ratio of retained earnings to equity as represented by net worth—the differences between assets and liabilities (Figure 6.15). If retained earnings had not kept up with total equity and enterprises had to resort more and more to equity markets, this ratio would have fallen over the period. Over the period 1965 to 1975—the period when the ratio of internal funds to fixed investment was relatively constant—the ratio of retained earnings to net worth fell, indicating a slight tendency to make more use of equity funds at this time. But over the period from 1976-1990, there is no trend in the ratio of retained earnings to net worth. It is not until the 1990s, when the amount of internal funds increased dramatically, that the balance sheet ratio of retained earnings to net worth began to increase.

To gauge the relative importance of debt, we plot the ratio of debt-to-total assets and debt-to-non-financial assets. The latter increased dramatically starting in 1975, thereby seeming to indicate that debt had become more important. However, the ratio of debt to total assets (which includes non-financial assets) remained constant. It appears that the increase in debt was used mainly to cover the increase in financial assets of the business sector—debt, as a ratio of total assets, remained constant.

6.4 Implications for capital-to-labour ratios

The preceding sections suggest that all components of business investment have not been constrained by the decline in savings. Investment in structures has declined, but investment in equipment has remained relatively constant as a proportion of GDP.

Ultimately, however, measures like labour productivity depend upon the capital stock per worker. The fact that investment as a percentage of GDP has remained relatively constant does not mean necessarily that capital per worker has increased. In this section, we examine the growth in capital per worker.

Investment has been sufficient to augment the capital-to-labour ratio, but the growth in this ratio after 1981 has been lower than in the period 1961-1981. Moreover, the rate of growth in the capital-to-labour ratio after 1991 has been essentially zero (Figure 6.16).

Separating trend from cyclical effects after 1981 is more difficult because of dramatic cyclical movements in the capital-to-labour ratio. Labour has displayed more variability during this period compared to previous periods. Nevertheless, whether we use peak-to-peak or trough-to-trough changes, the post-1981 picture is one of lower growth.

The movement in the aggregate capital-to-labour measure is affected by changes in the series of individual industries and of shifts in the relative importance of different industries.

In many industries, the capital-labour ratios have continued to rise since 1988 (Figures 6.17 to 6.19). Business services, fishing, retail trade, construction, finance, insurance and real estate, and communications grew in the latter part of the period.

However, in manufacturing, logging, accommodations, food and beverages, and mining and oil wells, the capital-to-labour ratios were relatively flat after 1988.

Two industries, transportation and agriculture, have declining capital-to-labour ratios. Transportation has been experiencing major restructuring, and agriculture has suffered a period of distressed prices.

Table 6.2 presents capital-to-labour ratios for all major industry groups for selected years, along with each industry's shares of labour and of the value of capital stock. The differences among industries are large. Some of the differences reflect patterns of ownership rather than use. In particular, the real estate industry owns buildings that are used by other industries. Many financial institutions also own buildings that are rented out to tenants in other industries. On the other hand, many service companies are retail outlets that rent space in buildings owned by others. In an attempt to remove the effects of these ownership patterns, a service sector is shown here that includes all of the wholesale and retail trade, finance, insurance, real estate and other service industries.

The trend in the overall capital-to-labour ratio reflects the joint effect of structural and technological changes. First, it is conceivable that technological changes associated with the new economy and the organizational changes to which it is giving rise require less capital than the systems they

Table 6.2 Effect of industrial shifts on the business sector capital-labour ratio

Industry	1966			1973			1979			1988			1997		
	Share of capital (%)	Share of labour (%)[a]	Capital-labour ratio ($000)[b]	Share of capital (%)	Share of labour (%)[a]	Capital-labour ratio ($000)[b]	Share of capital (%)	Share of labour (%)[a]	Capital-labour ratio ($000)[b]	Share of capital (%)	Share of labour (%)[a]	Capital-labour ratio ($000)[b]	Share of Capital (%)	Share of Labour (%)[a]	Capital-Labour Ratio ($000)[b]
Agricultural and Related Services	6.5	10.9	10.3	5.0	7.9	13.3	5.7	6.9	19.2	3.2	5.3	15.7	2.0	4.7	12.2
Fishing and Trapping	0.3	0.5	10.0	0.2	0.4	10.8	0.2	0.5	9.0	0.1	0.6	4.3	0.1	0.3	8.1
Logging and Forestry	0.6	1.5	7.2	0.5	1.2	8.5	0.4	1.1	9.1	0.2	0.7	6.2	0.1	0.7	6.5
Mining, Quarrying and Oil Wells	8.4	1.8	79.5	10.1	1.7	122.2	9.7	1.8	127.0	10.6	1.6	168.0	8.9	1.6	164.9
Manufacturing	14.4	27.6	9.0	14.6	27.2	11.3	13.4	24.8	12.6	12.0	21.7	14.4	10.8	19.3	16.2
Construction	0.9	11.4	1.4	0.9	10.5	1.7	1.1	9.6	2.7	1.1	9.5	3.0	1.2	8.6	4.0
Transportation and Storage	12.8	6.5	34.1	11.0	5.8	39.9	8.8	5.9	34.6	7.4	5.2	37.1	6.7	5.7	33.9
Communication and Other Utilities	17.2	2.6	115.8	18.6	2.8	140.0	21.1	3.1	156.6	20.1	3.3	160.5	20.1	3.2	180.4
Service Sector	37.1	35.2	17.9	39.2	42.4	19.4	39.6	46.4	19.8	45.4	52.0	22.7	50.0	55.9	25.8
WholesaleTtrade	1.3	5.6	4.0	1.0	6.8	3.2	0.9	6.8	3.2	0.8	6.5	3.3	1.3	7.3	4.9
Retail Trade	2.6	12.8	3.4	2.0	13.9	3.1	1.8	14.0	3.1	1.6	14.9	2.9	2.1	14.6	4.1
Finance, Insurance and Real Estate	32.3	4.1	136.4	33.4	5.3	131.8	33.7	6.1	127.4	38.5	6.8	148.1	41.2	6.2	190.3
Business Services	0.1	2.3	0.5	0.1	3.6	0.5	0.1	4.9	0.6	0.3	6.8	1.1	1.0	9.7	3.0
Educational Services	0.1	0.1	22.3	0.1	0.1	17.2	0.1	0.1	32.4	0.1	0.1	30.9	0.2	0.2	34.4
Health and Social Services	0.3	0.9	4.9	0.3	1.4	5.1	0.4	1.6	5.2	0.4	2.6	3.8	0.4	3.5	3.6
Accommodation, Food and Beverage Services	0.6	5.1	2.1	0.8	5.4	3.0	1.1	6.6	3.7	1.5	7.8	4.8	1.4	7.0	5.9

Notes: [a] Labour is measured in terms of hours worked;

[b] Capital stock is measured in 1992 prices and is taken as the truncated geometric estimate.

Figure 6.15 Financial structure ratios of the Canadian business sector

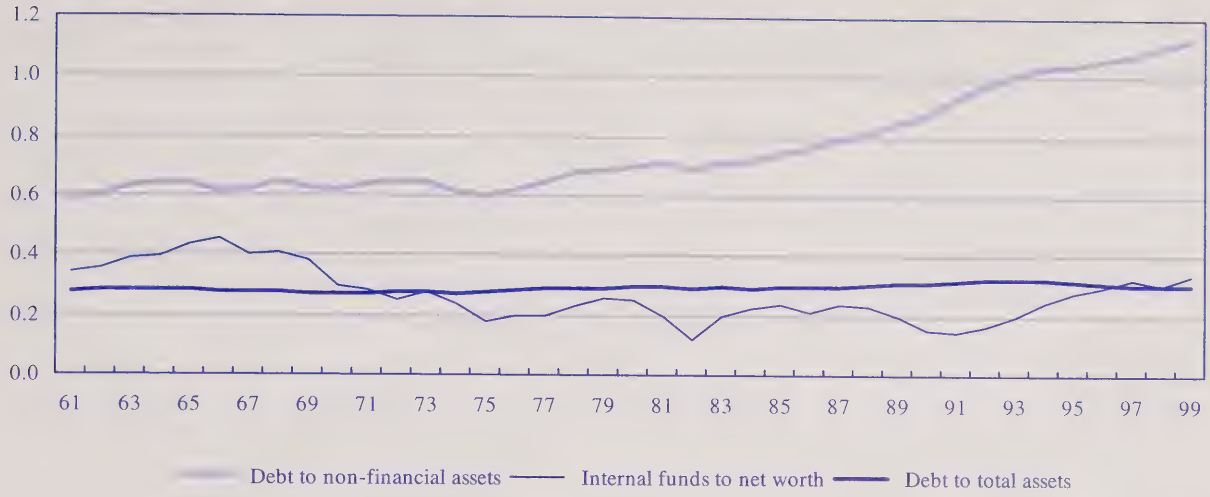


Figure 6.16 Capital-to-labour ratio for the Canadian business sector (1992 prices)

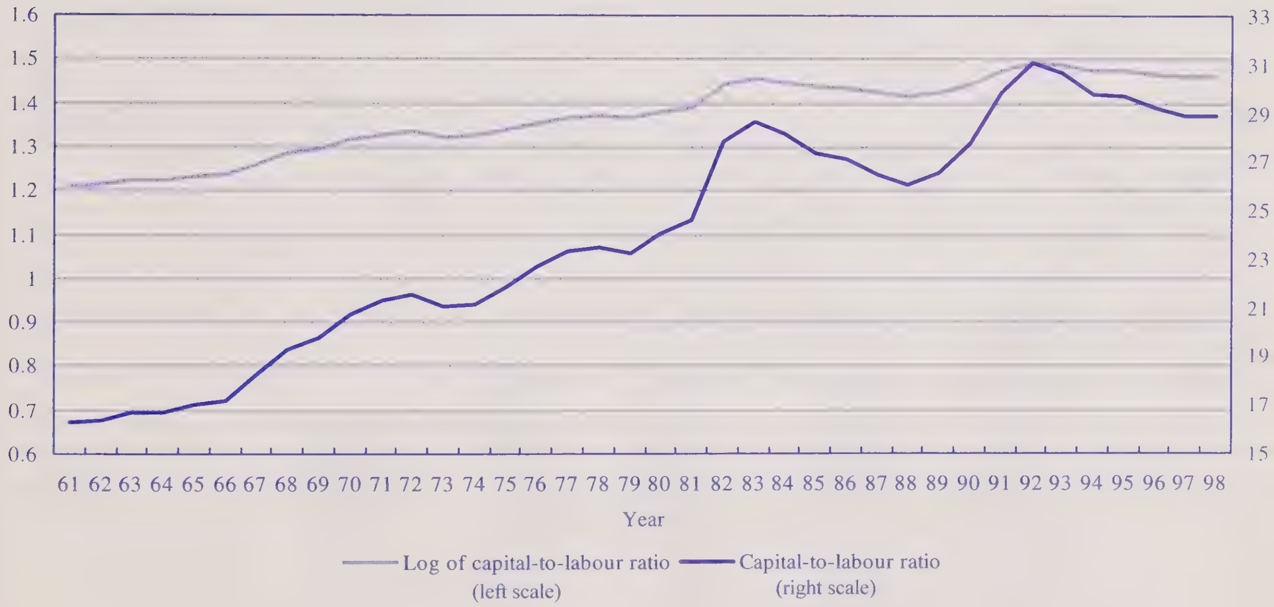
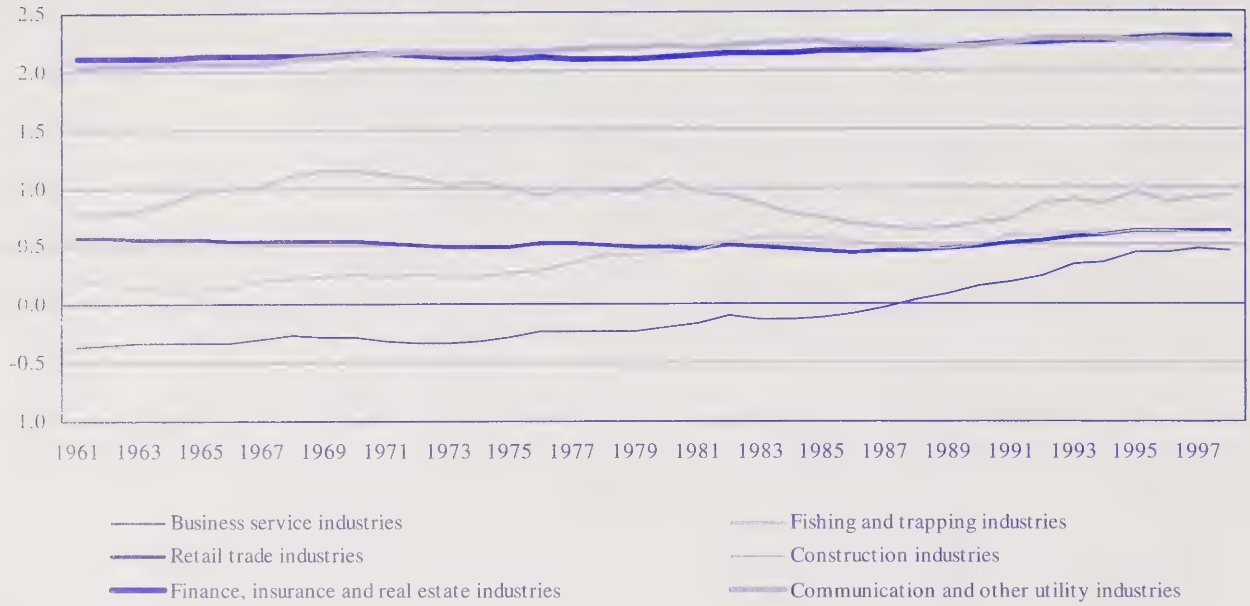
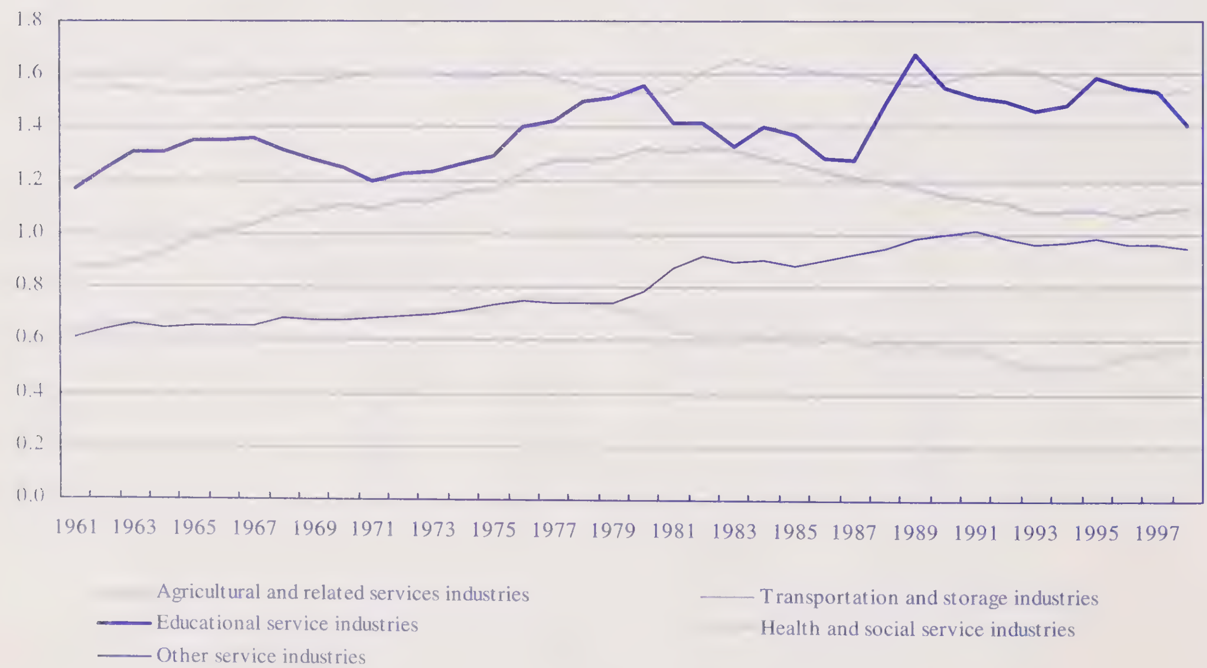


Figure 6.17 Capital-to-labour ratio, selected industries, Canada (1992 prices)[1]



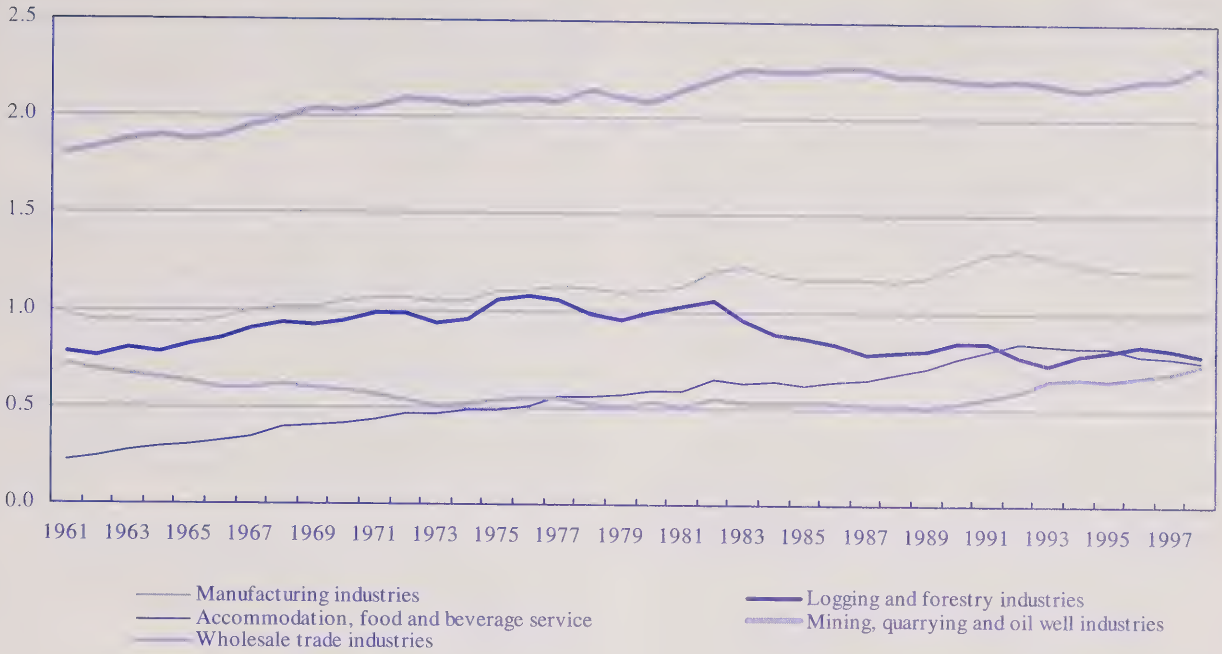
Note: 1. In logarithms.

Figure 6.18 Capital-to-labour ratio, selected industries, Canada (1992 prices)[1]



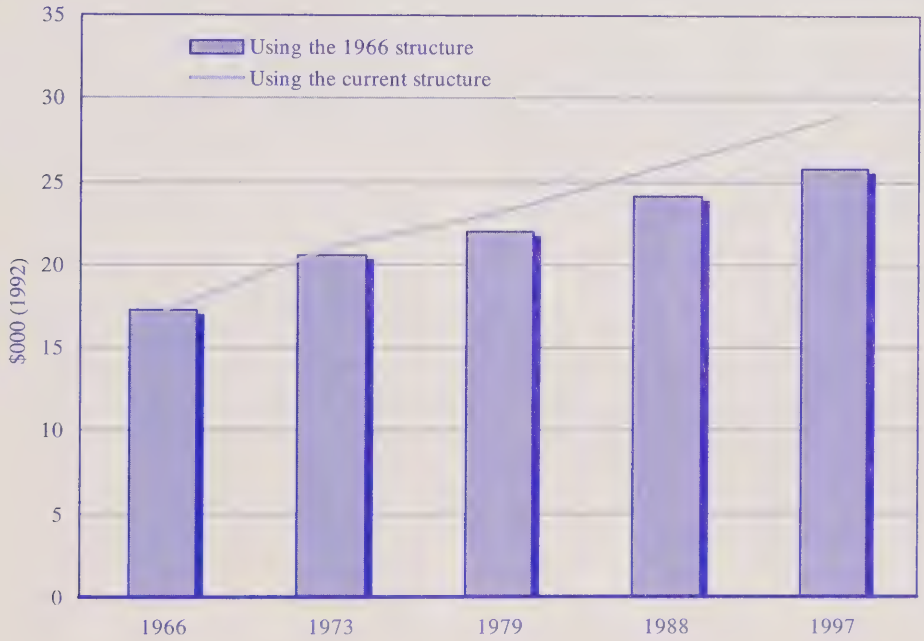
Note: 1. In logarithms.

Figure 6.19 Capital-to-labour ratio, selected industries, Canada (1992 prices)[1]



Note 1: In logarithms.

Figure 6.20 Capital-to-output ratio of the Canadian business sector, selected years



replace. There are instances where this appears to have occurred. Automated teller machines reduce the need for neighbourhood bank branches. The adoption of just-in-time inventory techniques reduces the need for warehouse capacity.

At the same time as these technological changes were occurring, structural shifts have resulted in the growth of some sectors at the expense of others. We perform a simple exercise to isolate the effects of structural change on the capital-to-labour ratio over the 1961-1997 period. We compare the actual increase in this ratio with the increase that would have occurred if all sectors had maintained their share of labour at the 1966 level.

Figure 6.20 depicts these two estimates of the business sector capital-to-labour ratios for 1966, 1973, 1979, 1988 and 1997, years that represent peaks of the business cycle. By using these years, we have attempted to provide estimates of the capital-to-labour ratio that are free of much of the influence of business cycles. The line is the observed capital-to-labour ratio and captures both structural and technological changes. The bars are derived by holding the labour shares constant at 1966 values and therefore captures only the effect of technological changes on the capital-labour ratio. Thus, the difference between the lines and the bar chart represents the net effect of structural changes on the capital-to-labour ratio.

From 1966 to 1997, the structural effect increased the capital-to-labour ratio by 18 percentage points, or 0.6% per year on average. Therefore, by holding constant the structure of the business sector, the capital-to-labour ratio would have grown at a slower pace. The bulk of this structural change is ascribed to growth in the services sector that experienced the largest increase in terms of size—more than 10 percentage points. Using the 1966 structure of the business sector attributes less importance to a sector whose capital-to-output ratio was larger than average and that grew at a rapid pace. In conclusion, structural shifts enhanced the aggregate capital-to-labour ratio over the period.

The absolute, though not the relative, contribution that this structural change has diminished over time. For the period 1966-1979, structural shifts accounted for about 5.1 out of the 34.7 percentage points of growth in the aggregate capital-to-labour ratio. Over the period between 1979 and 1997, structural shifts accounted for 3.5 out of 24.5 percentage points growth in the capital-to-labour ratio.

In summary, capital-to-labour ratios have been higher in the services sector than the average for all sectors. Thus, the rapid growth in the services sector, from 46% in 1979 to 56% in 1997 of hours worked, pulled up the overall ratio of capital-to-labour in the economy as a whole.

6.5 Conclusion

Investment spending has long been among the most closely watched elements of the national product accounts. During the past decade, the relative importance of investment in terms of output and the composition of investment in Canada changed dramatically. Workplaces were transformed as a result of investments in information processing equipment, such as computers, fax machines, copiers, and sophisticated telephones. Businesses have been purchasing more equipment than new office towers, shopping malls or other industrial facilities.

This chapter examines the pattern of investment in Canada and its composition across industries and assets since the early 1960s.

The chapter shows that while the savings rate dropped significantly over the last two decades, business investment has not borne the brunt of the lower savings rate. Declines in housing and government investment have cushioned the impact on business capital expenditures. The major drop in investment is caused by the drop in investment in structures; investment in machinery and equipment still remains high by historical standards.

In many respects, Canadian performance paralleled that of the United States. In both countries, the reduction in government investment, and non-residential structures bore most of the brunt of the investment slowdown. However there is one major difference. In the United States, investment in machinery and equipment increased as a share of GDP in the 1980s and 1990s, while in Canada, it remained relatively constant.

The chapter also asks whether changes in investment have been accompanied by changes in the sources of funds used to finance investment. The major drop in the business investment-to-GDP ratio in the early 1990s did not correspond to a relative decline in the funds that finance most business investment—funds generated internally. For most of the historical period, the corporate sector as a whole was self-financing; that is, funds generated internally more than covered fixed investments. Moreover, in the 1990s, this source actually exceeded fixed investments by a wide margin.

Finally, the chapter asks whether the changing investment intensity affected the amount of capital that is provided for the average worker. We find that the reduction in investment relative to GDP was accompanied by a slowdown in the growth of capital per worker. But the slowdown was not exacerbated by structural shifts away from goods industries towards services.

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7 The Cyclical Behaviour of Industrial Labour Productivity in Canada

John R. Baldwin and Tarek M. Harchaoui

7.1 Introduction

Productivity is procyclical. That is, whether measured as labour productivity or total factor productivity, productivity rises in booms and falls in recessions. The recent macroeconomic literature views this stylized fact as an essential feature of business cycles. Economists have long regarded the long-run labour productivity growth rate as being important for growth and well-being. Procyclical productivity, by contrast, has received less attention in the business-cycle literature. In the last two decades, fluctuations in productivity have taken centre stage in modelling output fluctuations and are now viewed as an essential part of the cycle.

This chapter investigates changes in the cyclical behaviour of labour productivity over time. Two of the most important characteristics that are examined here are the volatility and the persistence of short-run movements in the labour productivity of individual industries. Disaggregated industry data are used to analyse whether short-run fluctuations have become less extreme or erratic over time and whether the tendency of shocks to have a permanent or transitory effect has changed between the pre-1973 and post-1973 eras.

Another aspect of cyclical behaviour that is examined in the chapter is the correlation of short-run changes in the labour productivity series across industries (co-movements).[1] Does the productivity of various industries move together, as would be the case if sectoral shocks had large and rapid spillovers? Or do individual series move in different ways, as would be the case if isolated, industry-specific shocks were more important and there were few spillovers? Have there been changes in the relative importance of various types of shocks over time?

If individual industries respond to shocks in a similar way, this suggests that aggregate factors are important or that industry shocks have strong spillovers to other industries. If industries respond quite differently, this indicates that isolated industry-specific shocks explain most of the movement in the productivity of various industries. This aspect of short-run behaviour is clearly relevant to the question of whether there is in fact a business cycle, characterized by many individual series moving up and down in concert. The predominance of industry-specific shocks is consistent with the view that industries are shocked at different times and that linkages between industries are weak or occur with a substantial lag.

A related issue is the relative importance of technology shocks and demand shocks in causing short-run productivity fluctuations in the pre-1973 and post-1973 periods. The effects of demand shifts are arguably less long-lasting than the effects of technology changes. If so, a finding that movements in the individual series are quite temporary suggests that demand shocks are driving cyclical movements in productivity. On the other hand, a finding that movements in the individual series are very persistent could suggest that technology shocks predominate. Determining the source of shocks is important for deciding whether traditional sticky-price models or real business cycle models of fluctuations are more appropriate.

[1] To measure and analyse the changes in the volatility, persistence, and co-movement of short-run fluctuations in the industrial series of productivity estimates, we use simple summary statistics such as the standard deviation and the autocorrelations of the growth rates of labour productivity series at the industry level.

7.2 Volatility in industrial labour productivity

Of all changes in short-run behaviour that may have occurred over time, the one that has received the most attention is the possible change in the volatility of fluctuations.[2] Therefore, it is useful to examine whether the volatility of labour productivity has changed between the pre-1973 and post-1973 eras.[3] The standard deviation of log differences of the labour productivity of 37 industries, which shows the dispersion of the growth rates of a productivity series around its mean, provides a measure of the volatility of fluctuations in the various time periods.

Table 7.1 reports the standard deviations of each series for each period. The individual series within each time period have very different levels of volatility. For example, within the pre-1973 era, logging and forestry industries have a standard deviation that is almost twice that of printing, publishing and allied industries, but substantially smaller than that of textile products. These large differences in volatility suggest that individual industries are either subject to quite different shocks or respond very differently to common shocks.

A much more important finding is that there has been a significant change in the standard deviation of the growth rates of various productivity series between the pre-1973 and the post-1973 periods. A convenient way to examine how much volatility has changed over time is to examine the ratio of the post-1973 standard deviation to the pre-1973 standard deviation of each series. These volatility ratios are given in Table 7.1.

Figure 7.1 shows a histogram of these ratios for the 37 industries. The median volatility ratio is 1.31 and the mean is 1.26. The volatility ratios for most of the industries are well above 1. For the total sample, 65% of the industries have ratios higher than 1, and half have a ratio higher than 1.25. This higher post-1973 volatility is particularly noticeable for five industries that are commonly considered among the most important industries in the Canadian economy. As a percentage of the total economy GDP in current prices for the 1961-1996 period, construction accounted for 9.2%, retail trade for 7.5%, wholesale trade for 4.9% and transportation for 4%. These four industries, which altogether represent almost one-third of the economy, have volatility ratios higher than 1, thus suggesting an economy that has become more volatile.

The volatility ratios reveal differences in the amount of stabilization shown by industries across sectors. The volatility ratios of the primary sector's industries are almost evenly distributed over the range 0.7 to 1.6. This indicates that there is a substantial amount of variation in the behaviour of the primary sector's productivity. Indeed, about as many primary industries have become more volatile as have become less volatile over time. For the manufacturing sector, the volatility ratios are clustered in the range 0.7 to 1.9. A majority of manufacturing industries have shown a substantial increase in volatility between the pre-1973 and post-1973 eras. The non-financial services industries show the greatest tendency to become more volatile. Some 63% of the industries have volatility ratios higher than 1.26.

The fact that there has been an increase in the volatility of most individual productivity series between the pre- and post-1973 era suggests that there has been a consistent increase in the combined effect of the shocks experienced by the 37 industries and the reaction to these shocks.

7.3 Persistence in industrial labour productivity

The measure of dispersion represented by the variance of a series, provides only one measure its volatility. It captures the amplitude of the variation over time in a series. Other characteristics of interest are the length of time it takes a series to complete a cycle (its period) and its tendency to move in conjunction with other series (i.e., its co-movement, which will be discussed below). The last two characteristics allow us to investigate the issues of persistence and commonality. Are movements in the productivity of particular industries mostly permanent or mostly transitory, and has the persistence of increases in productivity series changed over time? Do productivity series of different industries move in step with one another? This information is useful for determining the nature of shocks and the appropriate model of short-term fluctuations for the pre-1973 and post-1973 eras.

The extent to which the effects of shocks persist over time has been the subject of extensive investigation over the past two decades. Following the seminal paper by Nelson

[2] See Altman (1992).

[3] This chapter uses a subset of the labour productivity series published by Statistics Canada at the M- level of aggregation. Out of the 39 industries for which labour productivity are published, we excluded personal and household service industries and other service industries. The remaining 37 industries used in this chapter are members of the following sectors: primary (industries 1-7), manufacturing (industries 8-29), non-financial industries (industries 30-37).

Table 7.1 Volatility ratios of the Canadian industrial labour productivity series, 1961-1996

	1961-1973 (1)	1973-1996 (2)	Column 2/Column 1 (3)
1. Agricultural and Related Service	0.127	0.085	0.673
2. Fishing and Trapping	0.099	0.145	1.459
3. Logging and Forestry	0.045	0.071	1.578
4. Mining	0.102	0.099	0.969
5. Crude Petroleum and Natural Gas	0.183	0.140	0.761
6. Quarry and Sand Pit	0.088	0.094	1.066
7. Service Industries Incidental to Mineral Extraction	0.098	0.065	0.665
8. Food	0.030	0.035	1.180
9. Beverage	0.059	0.047	0.796
10. Tobacco Products	0.076	0.087	1.135
11. Rubber Products	0.054	0.081	1.497
12. Plastic Products	0.064	0.047	0.735
13. Leather and Allied Products	0.029	0.047	1.590
14. Primary Textile	0.061	0.071	1.160
15. Textile Products	0.073	0.061	0.840
16. Clothing	0.029	0.050	1.753
17. Wood	0.051	0.063	1.241
18. Furniture and Fixture	0.045	0.073	1.601
19. Paper and Allied Products	0.037	0.071	1.908
20. Printing, Publishing and Allied	0.025	0.042	1.664
21. Primary Metal	0.045	0.069	1.536
22. Fabricated Metal Products	0.028	0.040	1.441
23. Machinery Industries (except Electrical Mach.)	0.032	0.055	1.714
24. Transportation Equipment	0.081	0.065	0.803
25. Electrical and Electronic Products	0.057	0.051	0.897
26. Non-metallic Mineral Products	0.054	0.052	0.965
27. Refined Petroleum and Coal Products	0.154	0.117	0.761
28. Chemical and Chemical Products	0.036	0.060	1.648
29. Other Manufacturing	0.041	0.053	1.313
30. Construction	0.052	0.072	1.377
31. Transportation	0.040	0.070	1.783
32. Pipeline Transport	0.117	0.043	0.367
33. Storage and Warehousing	0.085	0.068	0.802
34. Communication	0.025	0.040	1.582
35. Other Utility	0.041	0.054	1.326
36. Wholesale Trade	0.018	0.050	2.709
37. Retail Trade	0.025	0.052	2.070
Median	**0.052**	**0.063**	**1.313**

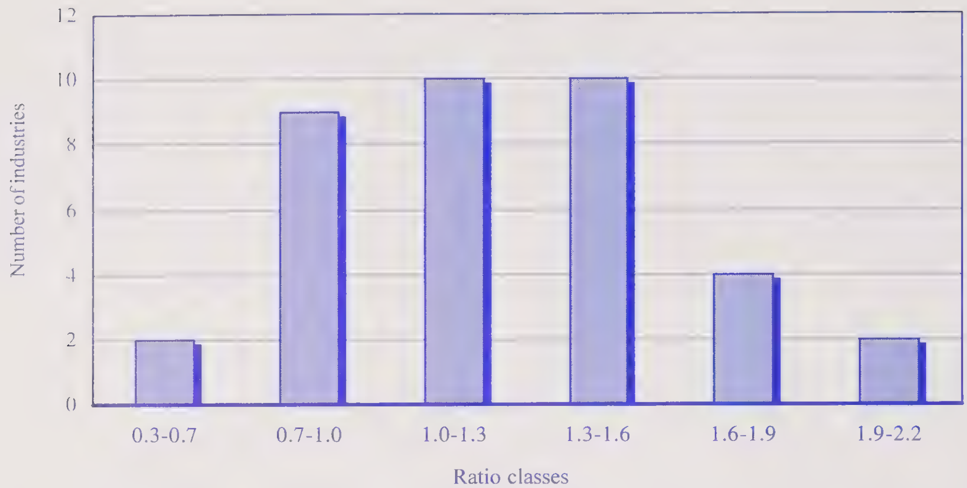
Note: The volatility ratios are calculated as the standard deviation of log differences of the labour productivity series of 37 industries within the 1961-1973 and 1973-1996 periods.

and Plosser (1982), aggregate output has been modelled by a first-difference stationary process, rather than by a stationary process around a deterministic trend. This has the important implication that macroeconomic shocks can have effects on output levels that continue into the indefinite future. An isolated recessionary shock may cause output growth to be temporarily lower than usual, but this would be reflected by a time path for the level of output that is permanently less than what it would have been in the absence of the shock.

The size of the long-run response of output to a unit shock, known as the persistence of shocks to output, is an empirical issue. Several studies have now been conducted to estimate the persistence measure for the real aggregate GDP. The evidence presented in these papers is mixed and inconclusive, largely reflecting the difficulties in determining the long-run properties of the aggregate output series (Pesaran et al. 1993).

In this section, we use the industrial labour productivity series in order to bring extra information to bear on the analysis of persistence at the aggregate level. A variance-ratio statistic is estimated with the same productivity series that were employed in the analysis of the volatility reported in section 7.2. A variance ratio is used to estimate the size of the random walk of the industrial productivity series.

Figure 7.1 Distribution of volatility ratios, 1961-1996



Cochrane (1988) has proposed the following variance-ratio (VR) estimate of the random-walk component:

$$VR(i,k) = \frac{Var\left(y_{t+k,i} - y_{t,i}\right)}{kVar\left(y_{t+1,i} - y_{t,i}\right)}. \tag{1}$$

This estimate compares the variance of the k difference of individual labour productivity growth rate series $\left(y_{t,i}\right)$ from industry i to k times the variance of the first difference of labour productivity for the same industry. If a series follows a random walk, the variance of the industrial productivity increases proportionally with k (k is the difference horizon). Therefore the variance of $y_{t+k,i} - y_{t,i}$ will equal k times the variance of $y_{t+1,i} - y_{t,i}$. This variance ratio can be estimated non-parametrically and the estimates are robust to heteroscedasticity and non-normal random disturbances.

Persistence is measured by the limit of the variance ratio, VR. For example, $VR = 1$ for a series that follows a random walk whereas $VR = 0$ for any trend stationary series.

The non-parametric estimates of VR for $k = 5$ are given in Table 7.2.[4] These estimates indicate that there has been an increase in the persistence of short-term fluctuations between the pre-1973 and the post-1973 eras for many industries. The median of VR is 0.37 in the pre-1973 era and 0.63 in the post-1973 era. For the industries with highest output share, there is more evidence of a change of persistence over time. For example, the VR for construction increased from 0.50 in the pre-1973 era to 1.133 in the post-1973 era, and for crude petroleum and natural gas industries, it increased from 0.474 to 2.252. This finding indicates that the effects of shocks on the major industries have become more persistent over time.

The significant change in the amount of persistence shown by most industries between the pre-1973 and the post-1973 eras suggests that some combination of the nature of shocks facing industries and the reaction of these industries to shocks has changed dramatically over time. If shocks had changed, say, from being primarily transitory demand shocks in the pre-1973 era to being permanent supply shocks in the post-1973 era, one would expect to see a noticeable change in the persistence of fluctuations in the productivity estimates of most industries between the two periods. Following this reasoning, the dramatic increase in persistence shown by many industries tends to suggest that permanent shocks became more important in the post-1973 era or that the ability of these industries to recover from shocks slowed over time.

[4] While arbitrary, the value of five years seems a reasonable time period over which the properties of the changes in productivity are examined.

Table 7.2 Measure of persistence of the Canadian industrial labour productivity series, variance ratios by industry, 1961-1996

Industry	1961-1973 (1)	1973-1996 (2)	Column 2/Column 1 (3)
1. Agricultural and Related Service	0.272	0.200	0.735
2. Fishing and Trapping	0.328	0.366	1.119
3. Logging and Forestry	0.828	0.854	1.032
4. Mining	0.033	0.736	22.566
5. Crude Petroleum and Natural Gas	0.474	2.252	4.750
6. Quarry and Sand Pit	0.642	0.771	1.201
7. Service Industries Incidental to Mineral Extraction	0.139	0.316	2.275
8. Food	0.318	0.343	1.078
9. Beverage	0.389	1.205	3.101
10. Tobacco Products	0.737	0.438	0.594
11. Rubber Products	0.138	0.555	4.016
12. Plastic Products	0.175	0.984	5.620
13. Leather and Allied Products	0.370	0.669	1.808
14. Primary Textiles	0.730	0.600	0.822
15. Textile Products	0.225	0.587	2.613
16. Clothing	0.656	0.528	0.805
17. Wood	0.527	0.703	1.335
18. Furniture and Fixture	0.281	0.378	1.342
19. Paper and Allied Products	0.466	0.175	0.377
20. Printing, Publishing and Allied	0.376	1.380	3.676
21. Primary Metals	0.151	1.324	8.777
22. Fabricated Metal Products	0.746	0.318	0.427
23. Machinery Industries (except Electrical Mach.)	0.444	0.369	0.830
24. Transportation Equipment	0.168	0.737	4.386
25. Electrical and Electronic Products	0.263	0.414	1.579
26. Non-metallic Mineral Products	0.545	0.687	1.261
27. Refined Petroleum and Coal Products	0.499	0.747	1.498
28. Chemical and Chemical Products	0.484	0.289	0.598
29. Other Manufacturing	0.255	0.486	1.905
30. Construction	0.500	1.133	2.264
31. Transportation	0.384	0.550	1.430
32. Pipeline Transport	0.328	1.632	4.979
33. Storage and Warehousing	0.096	0.515	5.353
34. Communication	0.334	0.852	2.552
35. Other Utilities	0.667	0.964	1.445
36. Wholesale Trade	0.341	0.839	2.458
37. Retail Trade	0.200	0.625	3.125
Median	**0.370**	**0.625**	**1.579**

Note: Estimates of persistence are based on the variance ratio (VR) proposed by Cochrane (1988). For example, $VR = 1$ for a series that follows a random walk (i.e., shocks have permanent effects), whereas $VR = 0$ for any trend stationary series (i.e., shocks have transitory effects).

In addition to examining possible changes in persistence over time at the industry level, it is also important to discuss the absolute level of persistence in the series of the various sectors before and after 1973. Do the estimates of VR suggest that fluctuations in the productivity series of particular sectors are mainly transitory or mainly permanent?

Table 7.2 shows that there is a noticeable difference in the level of persistence shown by the various sectors during the pre-1973 era. The median VR is roughly 0.33 for the primary sector, and 0.38 for the manufacturing sector. Not only are the estimates of VR moderately low for the majority of sectors but they are also not significantly different across major sectors. This clearly suggests that shocks tended to be transitory in the pre-1973 era and that sectors tended to behave similarly. The latter indicates that aggregate factors are important and affected each of the sectors in the same way or that sectoral shocks had weak spillovers to other sectors.

During the post-1973 era, shocks tended to be more persistent in comparison with the pre-1973 era for most sectors. The permanent effect of a shock is typically the longest for the non-financial services industry sector of the Canadian business sector. The estimates of VR for the primary sector indicate that a large fraction of the effects of a shock remains after several years, though shock effects are

less persistent than if the productivity of this sector actually followed a pure random walk. The manufacturing sector experienced a moderately high median of the VR estimates. One interpretation of the persistence of fluctuations in the manufacturing sector is that shocks to this sector tend to come at least partially from the supply side, which, we have argued are particularly likely to be long lasting. However, it could also indicate that demand shocks have had longer lasting effects in the post-1973 period. The possibility that demand shocks have very persistent effects is particularly likely for industry-specific shocks if they are related to restructuring or to long-lasting disinflations associated with recessions in the early 1980s and 1990s.

It is noteworthy to mention that persistence and volatility are not related across industries. At the industry level, there is no significant correlation between the volatility of the growth rate and the persistence measure, either in the first or the second period. Moreover, the increase in the volatility is negatively correlated (though not significantly so) to the increase in the persistence measure. If we can say that a substantial portion of the increase in volatility is related to macroeconomic fluctuations, then the industries that have been most affected by macroeconomic fluctuations are not those where changes in productivity have been most persistent.

7.4 Co-movement in industrial labour productivity

The previous analysis has looked at the volatility and persistence of productivity estimates at the industry and sectoral levels. We investigated whether shock effects tended to be transitory or permanent and whether this tendency has changed over time. This section investigates whether the changes in industry productivity in one industry are closely related to changes in another industry. Ascertaining whether the productivity of individual industries moves in concert or separately is useful because it helps to identify which of the two types of behaviour are consistent with the observed pattern of short-run fluctuations in productivity.

The predominance of a common aggregate factor behind movements in productivity is consistent with models of productivity fluctuations in which all industries move together because of common aggregate demand or aggregate technology shocks. It is also consistent with models in which sectoral shocks have rapid and extensive spillovers to other sectors (Long and Plosser 1983; Murphy, Shleifer and Vishny 1989). The predominance of industry-specific shocks is consistent with the view that industries are shocked at different times and that linkages between sectors are weak or occur with a substantial lag (Lilien 1982).

In this section, factor analysis is used to analyse whether short-run fluctuations in labour productivity are related to the predominance of common aggregate shocks or industry-specific shocks. Additionally, we will investigate the issue of changes in the relative importance of these two types of shocks over the periods 1961-1973 and 1973-1996.

Factor analysis with one common factor is a statistical procedure that decomposes the movement in each member of a series into the part that is due to a single unobserved common factor and the part that is due to a disturbance unique to the individual series.[5] In terms of the notation given in previous sections, factor analysis decomposes the annual growth rate of each productivity series $\left(y_{ti}\right)$ into the part that is due to a common disturbance $\left(C_t\right)$ and the part that is due to a series specific disturbance $\left(u_{ti}\right)$. That is

$$y_{ti} = \lambda_i C_t + u_{ti}, \qquad (2)$$

where the variable C_t, derived from the cross-sectional pair-wise correlations between the productivity growth rates of labour productivity across industries, is used to capture the importance of a common aggregate disturbance. It is assumed that u_{it} and C_t are uncorrelated and that the series-specific disturbances are uncorrelated across industries.

The squares of the $\hat{\lambda}_i s$ provide estimates of the fraction of the variance of the growth rate of each series that can be explained by the unobserved common factor. In what follows, this fraction is interpreted as showing the relative importance of aggregate shocks in determining the behaviour of disaggregated productivity series in various time periods. However, it is important to note that the common movement in the series need not come solely from aggregate shocks such as changes in the money supply or the price of oil. Rather, it could come from sectoral shocks that spread rapidly from one industry to another.

[5] See Long and Plosser (1987) for an application of this technique.

The estimates of the $\hat{\lambda}_i s$ (the factor pattern) provide additional information on the signs of the responses of individual productivity series to the common factor: a series with a negative $\hat{\lambda}_i$ tends to move contrary to the common factor, while a series with a positive $\hat{\lambda}_i$ moves in the same direction. Changes in these signs between time periods indicate whether the series have changed in their relationship to the common factor and implicitly, therefore, in their relationship to one another.

Table 7.3 presents the factor patterns for the 37 industries in the pre-1973 and post-1973 periods. In both periods, the fraction of the total variation that is accounted for by the single common factor is low. Most change at the industry level is idiosyncratic.

The importance of the common factor varies substantially across industries. For some industries, the fraction of total variation accounted for by the aggregate factor is very low in both periods; for most others, the aggregate factor appears to account for at least half of the total variation only in the post-1973 period. The greater prevalence of industries for which the common factor is unimportant is illustrated by the fact that the median $\hat{\lambda}_i^2$ is 0.07 in the pre-1973 period and 0.24 in the post-1973 period. Since the $\hat{\lambda}_i s$ are derived from the sample cross-correlations, the finding that the $\hat{\lambda}_i^2 s$ of many industries are low is indicative of the fact that the cross-correlation between most industries is very small.

It is noteworthy that agriculture typically has a lower fraction of total variation explained by the common factor than do mining industries or most manufacturing industries. This is consistent with the notion that the agricultural sector is subject to its own common shock. The unimportance of the aggregate factor for agriculture also carries over to some manufacturing industries that are closely tied to agriculture, such as tobacco industries.

The industries for which the aggregate factor is most important are the largest mining and manufacturing industries, construction industries and transportation industries. In keeping with this pattern, the common factor explains much more of the total variance of oil and gas industries in the post-1973 period than in the pre-1973 period. The mining and manufacturing industries that do not appear to be affected by the common factor are typically minor industries, such as quarry and sand pits, non-metallic mineral products, leather and allied products.

How can one explain the fact that the aggregate common factor accounts for more of the variance of major industries than of minor industries? One possible explanation is that producers within major industries differ systematically from those operating in minor industries in a way that increases their sensitivity to aggregate disturbances. For example, major industries may be more capital intensive, or they may tend to be more heavily unionized than minor industries. Both of these differences could cause productivity in larger industries to respond particularly strongly to aggregate shocks such as changes in monetary or fiscal policy.

In addition to showing the importance of aggregate shocks within each era, the separate factor analyses for the two sample periods allow us to examine changes in the importance of the common factor over time. Table 7.3 shows that, between the pre-1973 and post-1973 periods, there has been a significant change in the fraction of a given subsector's total variance that is explained by the common factor. The median $\hat{\lambda}_i^2$ for all 37 industries in the post-1973 period is 0.24, up from 0.07. This increased importance of the common factor in the post-1973 period is consistent with the notion that large and powerful aggregate shocks affected the Canadian economy in recent years.

In the presence of such a large aggregate shock, even the behaviour of minor industries that are not particularly sensitive to aggregate disturbances would have been affected by the aggregate shock. There is also a consistent difference in the change shown by major and minor industries and across subsectors. During the post-1973 period, for mining industries, the fraction of the variance explained by the common factor is over 0.5 for all but one industry (quarries and sandpits). For manufacturing, the fraction is quite high for most industries. As a result, this aggregate effect might be expected to dominate the impact of industry-specific shocks.

In addition to providing evidence on the relative importance of the common factor, factor analysis also indicates the sign of the sensitivity of the individual series to the common factor. The estimates of the $\hat{\lambda}_i$ in Table 7.3 show that, in both periods, mining and manufacturing industries typically respond positively to the common factor. While there are a few exceptions to this pattern, none of the negative coefficients are large.

The fact that the size of the factor pattern has changed substantially over time provides important evidence that the relationship between the various industries has changed between the pre-1973 and the post-1973 periods. More

Table 7.3 Coefficient on the common factor in industrial labour productivity, 1961-1996		
	1961-1973	1973-1996
1. Agricultural and Related Service	-0.181	-0.133
2. Fishing and Trapping	-0.084	-0.163
3. Logging and Forestry	0.571	0.632
4. Mining	0.452	0.752
5. Crude Petroleum and Natural Gas	0.523	0.814
6. Quarry and Sand Pit	0.324	0.441
7. Service Industries Incidental to Mineral Extraction	0.145	0.712
8. Food	0.293	0.746
9. Beverage	0.348	0.623
10. Tobacco Products	0.174	0.134
11. Rubber Products	0.152	0.399
12. Plastic Products	0.213	0.333
13. Leather and Allied Products	0.185	0.237
14. Primary Textiles	0.217	0.265
15. Textile Products	0.253	0.316
16. Clothing	0.322	0.397
17. Wood	0.381	0.582
18. Furniture and Fixture	0.222	0.281
19. Paper and Allied Products	0.383	0.556
20. Printing, Publishing and Allied	0.419	0.589
21. Primary Metals	0.282	0.634
22. Fabricated Metal Products	0.417	0.716
23. Machinery Industries (except Electrical Mach.)	0.389	0.479
24. Transportation Equipment	0.260	0.516
25. Electrical and Electronic Products	0.154	0.084
26. Non-metallic Mineral Products	0.195	0.136
27. Refined Petroleum and Coal Products	0.543	0.667
28. Chemical and Chemical Products	0.498	0.711
29. Other Manufacturing	0.121	0.086
30. Construction	0.488	0.689
31. Transportation	0.485	0.767
32. Pipeline Transport	0.117	0.332
33. Storage and Warehousing	0.186	0.375
34. Communication	-0.163	-0.066
35. Other Utilities	0.079	0.134
36. Wholesale Trade	0.317	0.486
37. Retail Trade	0.186	0.541
Median	**0.260**	**0.486**

Note: Estimates of the common factor $\hat{\lambda}_i$ are based on a statistical procedure that decomposes the movement of a series into the part that is due to a single unobserved common factor and the part that is due to a disturbance unique to the individual series. This procedure is known as factor analysis with one common factor. The u_{it} and C_t are assumed to be uncorrelated and the series-specific disturbances are uncorrelated across industries. The squares of the $\lambda_i s$ provide estimates of the fraction of the variance of the growth rate of each series that can be explained by the unobserved common factor.

generally, the existence of a major change in the relationship between industries suggests that the structural changes that have occurred over time have altered the basic production relationships in the economy.

It should also be noted that the importance of the common factor is positively correlated with the persistence measure across industries. Industries that are more affected by common shocks are more likely to experience persistence effects from these shocks—especially in the earlier 1961-73 period. Moreover, in the manufacturing sector, though not elsewhere, the increase in the importance of the common effect over time is strongly related to the increase in persistence.

7.5 Conclusion

This chapter has used an annual productivity series of 37 industries to examine the volatility, persistence, and co-movement of fluctuations in labour productivity over the period 1961-1996. The main finding is that there has been a significant change in the short-run behaviour of individual productivity series between the pre-1973 and the post-1973 periods. Fluctuations in the productivity series of the majority of industries are larger in the post-1973 period than in the pre-1973 period. Similarly, the persistence of fluctuations and the importance of aggregate disturbances for most industries have substantially changed over time.

In addition to indicating changes in the behaviour of productivity over time, this chapter has provided additional evidence of cross-sectional variations in industry performance. For example, estimates of persistence show that fluctuations in the productivity of individual mining industries and manufacturing industries are quite long lasting, particularly in the post-1973 period, though some of the effects of shocks are undone eventually. The results of a simple factor analysis show that most of the variation in the productivity of minor industries is due to the industry-specific shocks, while much of the variation in major industries is due to a common factor.

It is important to ask whether all of the changes described herein—greater volatility, greater persistence, and a greater importance of common shocks—are related. At the industry level, the answer is that the relationships are weak. The industries that have the greatest increase in volatility are not those that experience the greatest increase in persistence. Indeed, the correlation between the increase in volatility and the increase in other two factors is negative. Volatility, which is probably closely related to demand shocks, then appears to be driven by forces different from those that cause persistence.

On the other hand, increases in persistence are positively related to the existence of a common factor, primarily in the manufacturing sector. It is possible to argue that the increases in persistence and the importance of a common factor could also arise from demand shocks that became more severe in the post-1973 period. However, the fact that increases in persistance and the common factor were unrelated to increases in volatility suggest they were related to supply shocks associated with changes in technology or restructuring.

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8 Productivity Growth in the Canadian Manufacturing Sector: A Departure from the Standard Framework

JOHN R. BALDWIN, VALÉRIE GAUDREAULT AND TAREK M. HARCHAOUI

8.1 Introduction

Our interest in productivity growth arises from a desire to understand the process that generates economic growth.

The framework used to measure productivity growth decomposes output growth into two components. The first is the portion of output growth owing to increases in measurable inputs such as labour, materials, energy, services and capital. The remainder is caused by all other factors and is defined as productivity growth—or the growth in outputs that is not accounted for by the growth in inputs. It is a residual that measures all other factors contributing to output growth.

This residual can arise from a number of different sources. It can occur because firms have grown, possibly thanks to technological breakthroughs that allow them to exploit economies of scale. The residual can also arise from improved technologies that reduce costs for firms of all sizes.

Productivity growth measures produced by Statistics Canada and other statistical offices are based on an accounting framework that, for purposes of simplicity, assumes the instantaneous adjustment of inputs, no excess capacity, constant returns to scale, and perfect competition (i.e., price equals marginal costs). If one of these assumptions is violated, then the productivity residual will imperfectly measure the contribution of technological change to output growth.

Applied studies have suggested methods to estimate productivity growth that allow for scale economies (Denny, Fuss and Waverman 1981). They have also suggested methods to deal with problems that are caused by the fact that capital cannot be instantaneously adjusted, and that standard productivity estimates based on capital in place (rather than capital used) may contain biases (Berndt and Hesse 1985; Berndt and Fuss 1986).[1]

Bernstein and Mohnen (1991) and Morrison (1992) have developed an integrated econometric framework that makes adjustments in the standard estimates for scale economies, for imperfect input adjustments and for differences between prices and marginal costs. This is the framework that is adopted here and applied to detailed data on Canadian manufacturing industries over the 1961-1995 period.

[1] Hall (1988) and Domowitz, Hubbard and Petersen (1988) report significant markups of price over marginal cost in various manufacturing industries.

Statistics Canada's productivity estimates do not attempt to disentangle technological change from returns to scale. This chapter explores, in an experimental manner, the effect of relaxing the assumption that scale economies are not important.

The main purpose of this chapter is to measure the effect of modifying the standard productivity growth framework to remove the effects of scale economies. The chapter also investigates two other often-neglected areas.

First, it examines the validity of the assumption that markups—the deviation of price from marginal cost—are not important.

Second, it examines the effect of assuming that input markets adapt instantaneously. Most statistical offices assume that inputs are not marked by fixity. In reality, capital cannot be adjusted quickly. There are long periods over which capital is sometimes not fully utilized, when capacity utilization is less than 100%. While this problem has long been recognized, the solutions that have been chosen by statistical offices may not fully solve it.[2]

This chapter intends to decompose the standard estimate of productivity growth into two components: (1) that arising from scale economies and capacity fluctuations; and (2) the remaining residual. The latter has been referred to as the portion that really comes from technical progress as the 'true' productivity growth (Morrison 1992).

Our analysis begins in Section 8.2, where we outline the general framework taken from Morrison (1992) that accommodates the departure from the standard assumptions underlying the approach to productivity growth that underlies the estimates of most statistical agencies. Section 8.3 outlines the structural model used for empirical implementation and Section 8.4 presents the empirical results. The main conclusions of the chapter are summarized in Section 8.5.

Our principal findings indicate that the normal hypotheses used to estimate productivity—no markups, no fixity and constant returns to scale—are rejected. We also find that the assumption of constant returns to scale and full capacity tend to overestimate 'pure' technical change by roughly 30% over the period 1961 to 1995, but the estimate of this 'bias' is not very precise.

8.2 The analytical framework

8.2.1 The model and its role in assessing the issues

Productivity measures are meant to capture the increase in the efficiency of production over time. The concept of increasing efficiency can be formalized in either of two forms: (1) the growth in output when technology changes, holding the use of inputs fixed (the revenue or primal side); or (2) the diminution of costs for given levels of output and prices of inputs (the cost or dual side).

The primal approach measures productivity growth as the difference between output growth and input growth. The dual cost approach measures the difference between the rate of growth of unit cost and the rate of growth of the combined input prices—wage rates, energy and material costs.

[2] Because of the difficulty in precisely isolating the impacts of utilization on productivity, attempts to remove its effects often rely on calculating growth rates between cyclical peaks. This approach has drawbacks since identification of peaks can only be done after the fact.

If perfect competition, instantaneous adjustment (full capacity utilization) and constant returns to scale exist, $PY = C$ where Y is output, P is the corresponding price, and C is total costs, including only normal profits as a return on capital. This fundamental identity underlies the equivalency between output and cost-based measures of productivity. Therefore, when profits are zero, choosing the primal approach (focusing on the left-hand side of $PY = C$) is equivalent to the dual approach (focusing on the right-hand side of the expression).

To explain the theoretical linkages among productivity growth, scale economies, capacity utilization and markups, we describe the following in turn:

- how the primal and dual approaches to the measurement of productivity growth are related;
- how information on the relationship between costs and revenues should be incorporated into the cost and output shares used in the productivity growth computations; and
- how information on the returns to scale and the degree of capacity utilization can be combined within a unified framework to estimate a modified version of productivity growth that excludes their effects.

1) A general framework

a) Primal and dual non-parametric productivity frameworks

Consider the technology of firms to be characterized by a production function $Y = Y(X,t)$, or by a dual cost function $C = C(w,Y,t)$, where X is a vector of inputs, w is a corresponding vector of prices, and t denotes technical change. Then the elasticities of these functions with respect to t $\left(\varepsilon_{Yt} \equiv \frac{\partial \ell n Y}{\partial t} \text{ and } \varepsilon_{Ct} \equiv \frac{\partial \ell n C}{\partial t}\right)$ are referred to here respectively, as the primal and dual estimates of multifactor productivity growth. They reflect the residuals of total output (cost) growth less the contributions of the arguments of the functions other than t. The residual measure of technical progress—the growth in output that cannot be attributed to an increase in inputs or, conversely, the diminution of costs not explained by changes in input prices—has been denoted as the Solow residual (Solow 1958).

The traditional primal or output-side specification of multifactor productivity growth is written as

$$\begin{aligned}\varepsilon_{Yt} \equiv \frac{\partial \ell n Y}{\partial t} &= \frac{\left(\frac{dY}{dt}\right)}{Y} - \sum_{i=1}^{I} \frac{w_i X_i}{PY} \cdot \frac{\left(\frac{dX_i}{dt}\right)}{X_i} \\ &= \frac{\dot{Y}}{Y} - \sum_{i=1}^{I} s_i \frac{\dot{X}_i}{X_i},\end{aligned} \tag{1}$$

where the symbol '·' on each variable denotes a time derivative, and s_i is the share of input i in terms of the value of total output $\frac{w_i X_i}{PY}$.

With perfect competition, instantaneous adjustment and constant returns to scale, this is equivalent (except for a change in sign, so that $\varepsilon_{Ct} = -\varepsilon_{Yt}$) to the cost-side specification (Ohta 1975)

$$\varepsilon_{Ct} \equiv \frac{\partial \ell n C}{\partial t} = \frac{\left(\frac{dC}{dt}\right)}{C} - \frac{\left(\frac{dY}{dt}\right)}{Y} - \sum_{i=1}^{I} \frac{w_i X_i}{C} \cdot \frac{\left(\frac{dw_i}{dt}\right)}{w_i}$$
$$= \frac{\dot{C}}{C} - \frac{\dot{Y}}{Y} - \sum_{i=1}^{I} \omega_i \cdot \frac{\dot{w}_i}{w_i}, \tag{2}$$

where ω_i is the share of input i in terms of the total cost $\frac{w_i X_i}{C}$.[3]

The equivalence between the two approaches occurs because of the assumptions that there are no returns associated with a) technological characteristics such as economies of scale, b) the variation in the utilization of inputs,[4] and c) market power, implying that $s_i = \omega_i$.

b) Implications for the fundamental accounting identity

If the assumptions of perfect competition, full capacity utilization, and constant returns to scale are invalid, differences between revenue and costs will occur. For example, this can arise because non-constant returns to scale or fixity cause $AC \neq MC$ (where $AC = \frac{C}{Y}$ and $MC = \frac{\partial C}{\partial Y}$ denote, respectively, average cost and marginal cost) or because imperfect competition implies $P \neq MC$.

The simple identity between revenues and costs can be written as:

$$PY = C \cdot \frac{MC \cdot Y}{C} \cdot \frac{P}{MC} = C \cdot \frac{\varepsilon_{CY}}{\left(1 + \varepsilon_{PY}\right)} = C \cdot ADJ, \tag{3}$$

where ADJ is a factor that measures the extent to which revenue deviates from costs. This deviation arises from the fact that revenue—and therefore the revenue share appearing in (1)—embodies returns to all characteristics of the production process (including excesses of price over marginal revenue) that cause $PY \neq C$. However, costs C (and thus the cost shares) include only ex ante returns to inputs so (2) captures the effect of technical change independent of these other effects.

3 From the definition $C = \sum_i w_i X_i$, compute $\frac{\dot{C}}{C} = \sum_i \frac{w_i X_i}{C}\left(\frac{\dot{w}_i}{w_i} + \frac{\dot{X}_i}{X_i}\right)$. Substituting this result into the definition of the dual specification of multifactor productivity growth ε_{Ct} yields:
$\varepsilon_{Ct} = -\frac{\dot{Y}}{Y} + \sum_i \frac{w_i X_i}{C} \cdot \left(\frac{\dot{X}_i}{X_i}\right) = -\left(\frac{\dot{Y}}{Y} - \sum_i \frac{w_i X_i}{P_Y Y} \cdot \left(\frac{\dot{X}_i}{X_i}\right)\right) \equiv -\varepsilon_{Yt}$.

4 The value of marginal products of inputs just covers their hire cost, so full utilization is maintained.

This adjustment factor ADJ contains two elasticity expressions. The cost elasticity $\varepsilon_{CY} = \frac{\partial \ell n C}{\partial \ell n Y} = MC \cdot \frac{Y}{C}$ and the inverse demand elasticity $\varepsilon_{PY} = \frac{\partial P(Y,\Gamma)}{\partial Y} \cdot \frac{Y}{P}$, where $C = C(w,Y,t)$ and $P = P(Y,\Gamma)$, represent, respectively, the total cost function and the inverse demand function, and Γ is a vector of shift variables for the output demand function.

The equivalence of output and cost-based measures of productivity is destroyed when a firm either enjoys market power (for example, as a result of a factor such as product differentiation $\varepsilon_{PY} \neq 0$) or experiences non-constant returns (long-run fixities or short-run fixities) and, as a result, the scale estimate $\varepsilon_{CY} = \frac{MC}{AC}$ differs from 1 ($\varepsilon_{CY} \neq 1$).

Then the identity $PY = C$, upon which the equivalence of the primal and the dual approach depends, no longer holds. To re-establish the identity requires the use of the adjustment factor ADJ.

c) The relationship between scale economies and capacity utilization

Morrison (1985) has shown that the cost elasticity with regard to output can be divided into two components—an estimate of the long-run returns to scale, and capacity utilization:

$$\varepsilon_{CY} = \eta\left(1 - \varepsilon_{CK}\right) = \varepsilon_{CY}^{L} \cdot CU = \frac{MC \cdot Y}{C^*} \cdot \frac{C^*}{C}, \tag{4}$$

with $C(w,Y,t) = G(w',Y,K,t) + w_K \cdot K$, where $G(\cdot)$ is a variable cost function and K is the stock of capital, a quasi-fixed input, having an ex ante rental (market) price w_K, $\eta = \varepsilon_{CY}^{L} = \frac{MC \cdot Y}{C^*}$ is the inverse of long-run returns to scale and $CU\left(\equiv \frac{C^*}{C}\right)$ is the cost side measure of capacity utilization. The associated shadow cost function is defined $C^*(w,Y,t) = G(w',Y,K,t) + w_k \cdot K$, where $z = -\frac{\partial G}{\partial K}$ is the shadow price of K.[5]

Combining (3) and (4) gives the following modification that needs to be made to the fundamental identity between revenues and costs in recognition of the existence of non-competitive behaviour, fixity and returns to scale:

$$PY = C \cdot \frac{MC \cdot Y}{C^*} \cdot \frac{C^*}{C} \cdot \frac{P}{MC} = C \cdot \frac{\varepsilon_{CY}^{L} \cdot CU}{\left(1 + \varepsilon_{PY}\right)} = C \cdot ADJ. \tag{5}$$

Equation (5) indicates that the change in costs, as output varies, depends on the economies of scale parameter associated with the long-run average cost curve and the constraints of short-run input fixity that are reflected in the slope of the short-run curve (cost changes arising from potential returns to variable inputs in the short run). When

[5] $MC = \frac{\partial C}{\partial Y} = \frac{\partial G}{\partial Y}$ and $CU = \frac{C^*}{C} = 1 - \varepsilon_{CK}$, where $\varepsilon_{CK} = \frac{\partial C}{\partial K} \cdot \frac{K}{C} = \frac{(w_K + \frac{\partial G}{\partial K}) \cdot K}{C}$.

long-run constant returns to scale exist, $\varepsilon_{CY}^{L} = 1$, then all cost changes arising from output changes are associated with short-run returns to inputs. When instantaneous adjustment prevails, $\varepsilon_{CK} = 0$ and cost changes result only from movements along the long-run cost curve. This full equilibrium condition is equivalent to saying that $CU = 1$; capacity defined in terms of fixed inputs is fully utilized.

2) A simple framework to illustrate the problem

To explain the problems that arise from violations of the assumptions of constant returns to scale—full capacity and perfect competition—consider briefly the primal productivity estimate in the case where the production function can be characterized by a Cobb-Douglas functional form[6]

$$Y = K^{\alpha} L^{\beta} e^{\mu t}, \tag{6}$$

where Y is output, K is capital, L labour, t is an index of the state of the technology and α, β, μ are unknown parameters with $\alpha + \beta = 1$, which is required by the constant returns-to-scale assumption. The total derivative of (6) with respect to t yields

$$\begin{aligned} \frac{d\ell nY}{dt} &= \frac{\partial \ell nY}{\partial \ell nL} \cdot \frac{d\ell nL}{dt} + \frac{\partial \ell nY}{\partial \ell nK} \cdot \frac{d\ell nK}{dt} + \frac{\partial \ell nY}{\partial t} \\ \frac{\Delta Y}{Y} &= \alpha \frac{\Delta L}{L} + \beta \frac{\Delta K}{K} + \mu, \end{aligned} \tag{7}$$

where $\frac{\Delta Y}{Y}$ indicates the percentage change of Y (similarly for K and L). Recall that μ, which captures the shift of the production function (6), is identical to ε_{Yt} in (1). Therefore, rearranging (7), we now have multifactor productivity growth $(\mu \equiv \varepsilon_{Yt})$:

$$\varepsilon_{Yt} = \frac{\Delta Y}{Y} - \alpha \frac{\Delta L}{L} - \beta \frac{\Delta K}{K}. \tag{8}$$

To measure multifactor productivity growth, it is important to estimate the parameters α and β, since neither is directly observable. However, by assuming constant returns to scale (the total compensation of the inputs exhausts the total product: $PY = w_L + w_K$), perfect competition (the output price, which is identical to its marginal revenue, equals marginal cost: $P \equiv MR = MC$) and full capacity (the value of the marginal product of the inputs covers their hire cost: $P \frac{\partial Y}{\partial L} = w_L$ for labour, and $P \frac{\partial Y}{\partial K} = w_K$ for capital), one can get a direct measure of the parameters α and β:

$$\alpha = \frac{w_L L}{PY} \text{ and } \beta = \frac{w_K K}{PY}, \tag{9}$$

which constitute the compensation share of labour and capital in the nominal output, respectively.

[6] For the sake of simplicity we are assuming only two inputs, capital and labour.

Although competition in product markets is not perfect, a profit-maximizing firm will still set marginal revenue MR equal to marginal cost MC when it determines the factor input level, but price will be above marginal revenue (the amount of the difference being greater the more price-inelastic the demand curve). In this case, use of PY in the denominator of (9) that estimates the marginal product of labour α and the marginal product of capital β is inappropriate. Since $P > MR$, both α and β will be underestimated. In this case, the traditional multifactor productivity estimate has weights α and β that underestimate the portion of growth that comes from increases in the factors labour and capital. In turn, estimates of multifactor productivity will be biased upwards.

There are really two parts to the increase in output that would be expected from an increase in factor inputs. One part is due to the increase in factor use weighted by existing marginal products and the other to an increase in the value of marginal products arising from the exploitation of economies of scale as a plant increases in size. The latter is missed in estimates of multifactor productivity that assume constant returns to scale.

Appropriate corrections can be made to the denominators PY in (9) based on estimates of the ratio $\frac{P}{MR} = \left(1 + \varepsilon_{PY}\right)$ (where ε_{PY} is the inverse demand elasticity). This in turn can be calculated from estimates of the demand elasticity facing firms in an industry because a profit-maximizing firm is expected to set the price-cost markup ($\frac{(P-MC)}{MC}$) equal to the inverse of the demand elasticity it faces, and to set $MR = MC$. Using these two conditions, the ratio $\frac{P}{MR}$ can be calculated and P can be adjusted downward to equal MR, and a new set of weights can be devised to calculate multifactor productivity, which will be smaller than before.

It is also useful to examine the problems that arise from estimating multifactor productivity by using the dual to the production function. The dual total cost function C that corresponds to the Cobb-Douglas production function is[7]

$$C = e^{\gamma t} Q^{\frac{1}{(\alpha+\beta)}} w_L^{\frac{\alpha}{(\alpha+\beta)}} w_K^{\frac{\beta}{(\alpha+\beta)}}, \tag{10}$$

where γ is an unknown parameter. The dual multifactor productivity growth estimate derived from (10) $\left(\gamma \equiv \varepsilon_{Ct}\right)$ is simply

$$\varepsilon_{Ct} = \frac{\Delta C}{C} - \frac{1}{(\alpha+\beta)}\frac{\Delta Y}{Y} - \frac{\alpha}{(\alpha+\beta)}\frac{\Delta w_L}{w_L} - \frac{\beta}{(\alpha+\beta)}\frac{\Delta w_K}{w_K}. \tag{11}$$

Under the assumption of constant returns to scale, full capacity and perfect competition, $\varepsilon_{Ct} = -\varepsilon_{Yt}$. But if there are economies of scale $\alpha + \beta > 1$, then the estimates of the dual multifactor productivity growth would generally be smaller than are derived under the assumption of constant returns to scale.

[7] See Nerlove (1965) for an early treatment of the importance and equivalence of the dual cost function.

It is also useful to examine the effects of having prices not equal to marginal revenue on the estimation of the coefficients $\frac{\alpha}{(\alpha+\beta)}$ and $\frac{\beta}{(\alpha+\beta)}$ in this equation.

The first order conditions used to estimate the coefficients on the prices of labour and capital in the dual cost function are straightforward: the first derivative of the cost function, with respect to the price of a factor, is set equal to the quantity of the factor used (Shephard's lemma); that is $\frac{\Delta C}{\Delta w_L} = L$ for labour, for example, or it is expressed in terms of elasticity, $\frac{\Delta C}{\Delta w_L}\frac{w_L}{C} = \frac{w_L L}{C}$. Using (10), yields

$$\frac{\alpha}{(\alpha+\beta)} = \frac{w_L L}{C}, \tag{12}$$

and similarly for capital,

$$\frac{\beta}{(\alpha+\beta)} = \frac{w_K K}{C}. \tag{13}$$

It should be noted that a correct estimation of the parameters $\frac{\alpha}{(\alpha+\beta)}$ and $\frac{\beta}{(\alpha+\beta)}$ does not require the assumption that prices are equal to marginal revenue. It depends only on accurately estimating the share of labour and capital compensation in total costs. As long as costs are measured accurately,[8] the dual estimation technique removes the problem faced by the primal estimation technique of having to worry about whether marginal revenue can be replaced by prices. Of course, it is still necessary to accurately measure costs and to make sure that the costs of capital do not include any profits above those required to compensate capital for its opportunity cost.

8.2.2 The modified productivity measurement framework

Recognition of scale economies requires that a portion of output growth be attributed to the scale economies that cause output to grow more than proportionately to the increase in inputs. Relaxing the capacity utilization construct requires that we perform a similar exercise to take into account the portion of the output gains that are due to short-run scale economies that occur as a firm moves down a short-run cost curve towards full capacity.

Two corrections can be made to the standard dual of the cost-side methodological framework to allow for scale economies and short-run fixities in the capital stock.

1) Scale economies

First, to correct for $\varepsilon_{CY} \neq 1$ owing to scale economies, the residual that is normally estimated, ε_{Ct}, can be adjusted to yield the appropriate measure $\varepsilon_{Ct}^{\text{scale}}$, (Morisson 1992):

[8] We return to the same problem we faced in the primal case if we replace costs with revenues in the estimation process of the dual; that is, we set costs equal to revenues for the estimation of input compensation shares.

$$
\begin{aligned}
\varepsilon_{Ct}^{\text{scale}} &= \frac{\dot{C}}{C} - \varepsilon_{CY}\frac{\dot{Y}}{Y} - \sum_{i=1}^{I}\omega_i \cdot \frac{\dot{w}_i}{w_i} \\
&= -\varepsilon_{CY}\frac{\dot{Y}}{Y} + \sum_i \omega_i \left(\frac{\dot{X}_i}{X_i}\right) \\
&= \varepsilon_{Ct} + \left(1-\varepsilon_{CY}\right)\frac{\dot{Y}}{Y}.
\end{aligned}
\tag{14}
$$

The last term $\left(1-\varepsilon_{CY}\right)\frac{\dot{Y}}{Y}$ is the amount that should be subtracted from the traditional measures $\left(\varepsilon_{Ct}\right)$ when constant returns to scale are assumed inappropriately. The adaptation in (14) reflects the fact that $\varepsilon_{CY} = \frac{MC}{AC}$. Thus, the adjustment by ε_{CY} restates the change in output in terms of its correct marginal value. Costs should not be expected to increase proportionately to output, as in equation 2, when there are economies of scale. The impact of this adjustment on traditional estimates of multifactor productivity depends on the extent of scale economies and output growth.

2) Imperfect capacity utilization

If instead $\varepsilon_{CY} \neq 1$ because $\varepsilon_{CK} \neq 0$ as a result of short-run capital fixity and, therefore, sub-optimal capacity utilization, the valuation of the quasi-fixed input at the market rental price w_K is erroneous. The valuation should instead be made in terms of the shadow value z, reflecting the true marginal product of capital. This implies an adjustment for the numerator of the share weight on the quasi-fixed input change as well as for the denominator on weights of all inputs and outputs to reflect the fact that costs should be measured as C^* not C.

This adjustment is required because the derivation of the expression measuring productivity using the dual cost approach depends on the use of Shephard's lemma to make the substitution of X_i, the cost-minimizing demand for input i, for $\frac{\partial C}{\partial w_i}$. If capital is a quasi-fixed factor, this is not valid because the firm will not be able to instantaneously choose a cost-minimizing quantity for K. When this occurs, valuation of the changes in K should be made at the shadow value z instead of w_K, and input shares should be measured in terms of C^*.

Non-optimal use of the fixed inputs implies $\varepsilon_{CY} = 1 - \varepsilon_{CK} = \frac{C^*}{C} \neq 1$. The expression for ε_{Ct} can be adjusted to yield the appropriate measure $\varepsilon_{Ct}^{\text{fixity}}$ (Morisson 1992):

$$
\begin{aligned}
\varepsilon_{Ct}^{\text{fixity}} &= \left(1-\varepsilon_{CK}\right)\cdot\frac{\dot{Y}}{Y} - \frac{z\cdot K}{C}\cdot\frac{\dot{K}}{K} - \sum_i \frac{w_i \cdot X_i}{C}\cdot\frac{\dot{X}_i}{X_i} \\
&= \varepsilon_{Ct} + \varepsilon_{CK}\left(\frac{\dot{Y}}{Y} - \frac{\dot{K}}{K}\right).
\end{aligned}
\tag{15}
$$

As before, the last term in this expression can be thought of as a correction that is required if instantaneous adjustment is assumed when subequilibrium really exists. The correction depends in part on the relative growth rates of output and the quasi-fixed input K. Equation (15) has an intuitive interpretation: under the conditions of constant returns to scale, full capacity utilization and perfect competition, the dual ε_{Ct} and primal ε_{Yt} measures of multifactor productivity coincide. Therefore ε_{Ct} can be measured as the weighted sum of the labour productivity and capital productivity, that is, $\varepsilon_{Ct} = -\left[\frac{w_L L}{C}\left(\frac{\dot{Y}}{Y} - \frac{\dot{L}}{L}\right) + \frac{w_K K}{C}\left(\frac{\dot{Y}}{Y} - \frac{\dot{K}}{K}\right)\right]$. Because capital is fixed in the short run, w_K does not properly measure the value of the marginal product of capital. A correction that accounts for the discrepancy between the rental price of capital and its shadow price should therefore be introduced in the above formula. The adjustment factor is $\varepsilon_{CK}\left(\frac{\dot{Y}}{Y} - \frac{\dot{K}}{K}\right) = \frac{(w_K + \frac{\partial G}{\partial K})K}{C}\left(\frac{\dot{Y}}{Y} - \frac{\dot{K}}{K}\right) = \frac{(w_K K - zK)}{C}\left(\frac{\dot{Y}}{Y} - \frac{\dot{K}}{K}\right)$.

3) An integrated framework

Generating a fully adjusted measure of technical change from the cost side, incorporating both fixity and returns to scale, requires combining (14) and (15) as in Morrison (1992). This measure, denoted $\varepsilon_{Ct}^{\text{full}}$, accommodates the full adjustment in the standard ε_{Ct} measure:

$$
\begin{aligned}
\varepsilon_{Ct}^{\text{full}} &= -\varepsilon_{CY}\frac{\dot{Y}}{Y} + \sum_i \omega_i \left|\frac{\dot{X}_i}{X_i}\right| + \frac{z \cdot K}{C} \cdot \frac{\dot{K}}{K} \\
&= \varepsilon_{Ct} - \varepsilon_{CK} \cdot \frac{\dot{K}}{K} - (\varepsilon_{CY} - 1)\frac{\dot{Y}}{Y} \cdot
\end{aligned}
\qquad (16)
$$

The long-run scale elasticity correction factor recognizes that part of the cost change (reduction) is the result of economies of scale. The fixity correction recognizes that part of the change is due to the fact that the increase in capital used is not the same as the increase in total capacity of capital.

Once these adaptations of standard productivity growth measures are made, the traditional dual measure of productivity growth can be decomposed into scale and fixity effects and a residual that Morrison (1992) has referred to as the 'true' productivity growth.

8.3 Empirical implementation

In order to implement the framework developed in the previous section, estimates are required of scale economies, capacity utilization and markups. This is done here in three steps. First, short-run elasticities are estimated from a restricted cost function, which in turn is used to estimate the capacity utilization in the economy. Second, long-run scale elasticities are estimated from short-run elasticities and capacity utilization. Third, the inverse demand function is estimated to yield price elasticities that in turn are used to estimate the price-marginal cost mark-up.

8.3.1 Econometric specification

The basic building block of our model is a translog restricted cost function and a similarly constructed output demand function. The non-constant returns to scale translog cost function has the following forms:

$$
\begin{aligned}
\ell n\left(\frac{G_h}{w_{sh}}\right) = {} & \beta_{oh} + \sum_i \beta_{ih} \ell n v_{ih} + \beta_{Yh} \ell n Y_h + \beta_{Kh} \ell n K_h + \beta_{th} t + \\
& \beta_{YYh}\left(\ell n Y_h\right)^2 + \beta_{KKh}\left(\ell n K_h\right)^2 + \beta_{tth} t^2 \\
& + \sum_{i \neq j} \sum_j \beta_{ijh} \ell n v_{ih} \ell n v_{jh} + \sum_i \beta_{iYh} \ell n v_{ih} \ell n Y_h \\
& + \sum_i \beta_{iKh} \ell n v_{ih} \ell n K_h + \sum_i \beta_{ith} \ell n v_{ih} t \\
& + \beta_{YK} \ell n Y_h \ell n K_h + \beta_{Yth} \ell n Y_h t + \beta_{Kth} \ell n K_h t
\end{aligned}
\tag{17}
$$

$$i, j = L(\text{labour}), E(\text{energy}), M(\text{material}) \text{ and } S(\text{services});\ h = 1, 2, \ldots, h.$$

The subscripts i and j denote the variable inputs L, E, M and S, while h is an industry index. In this framework, labour input, measured in terms of hours worked, is assumed to be optimally adjusted within a year. A similar assumption is made for the intermediate inputs E, M and S. In contrast, because of gestation lags and other types of inertia, adjustment of the capital stock is assumed to be slower.

The variable cost G_h is defined as $G_h = \sum_i w_{ih} X_{ih}$ where w_{ih} and X_{ih} refer to the prices and quantities of the variable inputs L, E, M and S; and v_{ih} is the relative input price, defined as $v_{ih} = \frac{w_{ih}}{w_{sh}}$, where w_{sh} is the price of service inputs.

The corresponding inverse demand function for output is $P(Y, \Gamma)$ where Y represents the output and Γ is a vector of shift variables. These variables include the interest rate r, the implicit price index of goods and services P_{gs}, and the unemployment rate u. The inverse demand function is written as

$$
\begin{aligned}
\ell n P_h = {} & \theta_{oh} + \theta_{Yh} \ell n Y_h + \theta_r \ell n r + \theta_{gs} \ell n P_{gs} + \theta_u \ell n u + \theta_t t \\
& + \theta_r (\ell n r)^2 + \theta_{gs}\left(\ell n P_{gs}\right)^2 + \theta_u (\ell n u)^2 + \theta_{tt} t^2.
\end{aligned}
\tag{18}
$$

The inter-industry differences are captured in our estimation through the following parameterization of the cost function: $\beta_{oh} = \beta_o + \sum_h \alpha_{oh} D_h$, $\beta_{ih} = \beta_i + \sum_h \alpha_{ih} D_h$, where the parameters α_{jh} are normalized with respect to the k industry $\left(\alpha_{jk} = 0\right)$; D_h refers to the industry dummies taking values 1 and 0, and h, as noted earlier, is the industry identification index (similarly, we have $\theta_{oh} = \theta_o + \sum_h \alpha_{oh} D_h$ for the inverse demand function).

Table 8.1 Manufacturing industries

Food and Beverages	Refineries
Tobacco	Rubber
Textile	Leather
Clothing	Non-metallic Mineral
Wood and Lumber	Primary Metal
Furniture and Fixtures	Fabricated Metal
Paper	Machinery
Printing and Publishing	Electrical and Electronic
Chemical	Transportation Equipment

In our estimation, we have allowed for specific industry effects, that is,

$\beta_{Yh} = \beta_Y + \sum_h \alpha_{Yh} D_h$, $\beta_{Kh} = \beta_K + \sum_h \alpha_{Kh} D_h$,
$\beta_{th} = \beta_t + \sum_h \alpha_{th} D_h$, $\beta_{ijh} = \beta_{ij} + \sum_h \alpha_{ijh} D_h$,
$\beta_{iYh} = \beta_{iY} + \sum_h \alpha_{iYh} D_h$, $\beta_{iKh} = \beta_{iK} + \sum_h \alpha_{iKh} D_h$ and
$\beta_{ith} = \beta_{it} + \sum_h \alpha_{ith} D_h$ (similarly, we have $\theta_{Yh} = \theta_Y + \sum_h \alpha_{Yh} D_h$ for the price equation).

The system of equations (17), along with its associated share equations, should satisfy the usual regularity conditions.[9] We also assume that the error terms attached to the above equations are optimizing errors and are jointly normally distributed with zero expected value, and with a positive definite symmetric covariance matrix.

The system of equations used to estimate the parameters required by our measurement framework includes the cost function (17), the demand functions for L, E and M, and the output demand equation (18).[10]

8.3.2 Data and estimation

Estimation of the system (17) was carried out using Canadian manufacturing data for the period 1961 to 1995. In addition to estimates for the 18 manufacturing industries listed in Table 8.1, we also derived an estimate for the entire manufacturing sector by aggregating data across industries using Fisher indices.[11]

[9] In particular, for the cost function to be concave in input prices, its Hessian matrix $\left[\frac{\partial G}{\partial w_i \partial w_j}\right]_{ij}$ of second-order derivatives with respect to variable input prices should be negative semi-definite. In addition, the cost function should be non-decreasing in output and linearly homogeneous in input prices.

[10] Applying Shephard's lemma, the following share equations are obtained: $\omega_{ih} = \beta_{ih} + \sum_i \beta_{ih} \ell n v_{ih} + \sum_i \beta_{iYh} \ell n Y_h + \sum_i \beta_{iKh} \ell n K_h + \beta_{ith} t$, where $\omega_{ih} = \frac{w_{ih} \cdot x_{ih}}{G_h}$. The share of the service inputs is calculated as $\omega_{sh} = 1 - \sum_i \omega_{ih}$, since there are only $n-1$ independent equations in the model.

[11] See the methodology in Appendix 1 for the method of Fisher aggregation used.

Table 8.2 Descriptive statistics of industries 1961 to 1995											
	$\dot{G}$	ω_L	ω_E	ω_M	ω_S	$\dot{Y}$	$\dot{L}$	$\dot{E}$	$\dot{M}$	$\dot{S}$	$\dot{K}$
					mean values						
Food and Beverages	7.0	18.0	1.3	67.2	13.6	7.4	-0.1	1.0	2.8	2.2	1.9
Tobacco	4.9	19.2	0.5	64.1	16.2	6.1	-2.8	1.6	-0.4	1.1	-0.1
Textile	6.0	29.0	2.1	57.0	11.9	8.2	-0.1	2.6	3.1	2.3	1.5
Clothing	5.5	36.3	0.5	51.1	12.0	12.8	-0.9	2.3	2.2	0.5	1.6
Wood and Lumber	9.2	32.5	2.3	51.6	13.6	3.5	0.8	4.1	4.3	4.0	2.6
Furniture and Fixtures	8.0	39.0	1.1	44.2	15.8	5.1	1.4	2.9	3.4	3.8	2.4
Paper	8.5	27.9	7.1	50.8	14.2	7.9	0.2	2.8	3.2	4.3	3.5
Printing and Publishing	8.5	46.3	0.8	32.6	20.4	5.8	1.5	3.6	3.2	3.9	3.1
Chemical	8.9	23.5	5.9	48.0	22.6	9.5	0.9	4.6	4.2	3.5	3.4
Refineries	8.6	6.0	2.0	77.9	14.1	8.3	-0.3	6.3	2.0	2.4	0.4
Rubber	10.3	32.0	1.9	51.6	14.6	8.7	3.8	7.0	6.7	5.9	3.9
Leather	3.4	36.9	0.9	48.4	13.9	8.7	-3.1	-1.7	-1.6	-0.7	0.2
Non-metallic Mineral	7.2	34.1	6.7	40.5	18.7	7.9	0.0	0.7	2.5	2.2	-0.1
Primary Metal	7.9	23.0	7.3	57.9	11.9	8.0	0.0	2.3	3.0	2.6	2.2
Fabricated Metal	7.9	34.5	1.2	51.8	12.5	10.0	1.3	2.6	2.9	3.1	1.0
Machinery	9.1	34.7	1.0	51.2	13.1	11.9	1.9	3.2	5.6	4.4	2.9
Electrical and Electronic	9.3	34.2	0.8	51.7	13.3	9.3	0.8	2.9	7.5	4.4	3.3
Transportation Equipment	11.8	21.9	0.7	65.7	11.6	7.2	2.6	4.5	7.0	6.6	5.2

Notes:

$G = \sum_i w_i X_i$ = variable cost function, with $i = L(\text{labour}), E(\text{energy}), M(\text{materials})$ and $S(\text{services})$

s_i = cost share of variable input i

$\dot{G}$ = growth rate of the variable cost $\dot{Y}$ = growth rate of real gross output $\dot{L}$ = growth rate of hours

$\dot{E}$ = growth rate of energy input $\dot{M}$ = growth rate of materials input $\dot{S}$ = growth rate of services input

$\dot{K}$ = growth rate of capital stock net of truncated geometric depreciation

The data used are series on prices and quantities of output, capital, labour, energy, materials and services from Statistics Canada's productivity program.[12] Table 8.2 provides the mean values of the cost, input shares and the growth rates of gross output and the inputs for each industry. There are considerable variations among the industries in the cost, output and input growth rates. There are some differences among the input shares as well. Labour shares range from 6% for petroleum refineries to 46% for printing and publishing. Materials' shares range from 33% for printing and publishing to 78% for refineries. These inter-industry variations encourage the use of a specification that captures industry idiosyncrasies.

The estimation model consists of the restricted cost equation from which we construct the elasticity measures described in Section 8.3, the share equations for labour, energy and materials and the output demand equation. The share equation of services is obtained residually because of the constraint that variable cost shares must sum to one. We have pooled time-series cross section data for 18 two-digit Canadian manufacturing industries for the period 1961 to 1995 to estimate the model. Estimating the model as a pooled system not only adds structure to the model (additional degrees of freedom) but also imposes cross-equation restrictions to allow a fully integrated input-demand and output-supply model, facilitating more efficient estimates. Seemingly

[12] See Appendix 1 for the sources and concepts underlying the productivity program.

unrelated regressions (SUR) techniques were used for estimation, since the equations share common parameters.[13]

The results of the hypothesis tests using log-likelihood ratios decisively reject the joint hypothesis that the dummy industry coefficients are zero, indicating that strong inter-industry differences are present in the cost structure of the industries under consideration. The results also indicate that the model is well estimated.The square of the correlation coefficients between the actual and predicted values is high, and the standard errors of each equation are small. In addition, all the required regularity conditions are satisfied at each point in the sample. The estimates revealed that the coefficients of the model are statistically significant and have the correct sign.[14]

We also test the hypothesis that firms operate under a constant returns-to-scale technology, i.e., $\varepsilon_{CY} = 1$. The test is computed by subtracting from the consistent parameter estimates obtained from estimating the system of equations (17)—call them $\hat{\varepsilon}_{CY}$—the consistent parameter estimates obtained under the alternative hypothesis, i.e., the parameter estimates, $\tilde{\varepsilon}_{CY}$, obtained from equations system (17) with $\varepsilon_{CY} = 1$. Then the vector of parameter differences is standardized by the difference of the covariance matrices of the two sets of estimates, i.e., $M = \left(\hat{\varepsilon}_{CY} - \tilde{\varepsilon}_{CY}\right)' \left\{Cov\left(\hat{\varepsilon}_{CY}\right) - Cov\left(\tilde{\varepsilon}_{CY}\right)\right\}^{-1}\left(\hat{\varepsilon}_{CY} - \tilde{\varepsilon}_{CY}\right)$. The quadratic form computed in this way is asymptotically chi-squared with degrees of freedom equal to the number of parameters of the imposed condition. The results of our tests indicate that $M = 196 > \chi^2_{95:.005} = 134$, and thus we reject the hypothesis that firms operate under constant returns to scale. Similarly, the hypotheses that firms do not operate under constraints of fixity, $\varepsilon_{CK} = 0$, that there is no technical change, $\varepsilon_{Ct} = 0$, and output markets are competitive, $\varepsilon_{PY} = 0$, were separately tested. Each of these hypotheses was rejected $M = 210 > \chi^2_{95:.001} = 134; M = 157 > \chi^2_{95:.001} = 134;$ $M = 166 > \chi^2_{95:.001} = 114$, respectively.

8.4 Analysis of results

8.4.1 The standard non-parametric productivity growth measure

Traditional non-parametric multifactor productivity growth indices ε_{Yt} based on the K, L, E, M, S division of inputs are presented in terms of average annual growth rates in Table 8.3, and in their full form (from 1961 to 1995) in Appendix Table 8.1A. These measures are computed using standard primal-side measurement techniques, ignoring the potential existence of markups, input fixity and returns to scale.

[13] The model was also estimated for each industry, using three-stage least squares to incorporate the endogeneity of output quantity and price, and to allow for the possibility of non-static expectations on input prices as outlined by Pindyck and Rotemberg (1983). The instruments employed included lagged values of exogenous variables facing the firm, defence spending and the world oil price. Although the parameter estimates for $\varepsilon_{Ct}, \varepsilon_{CY}$ and ε_{CK} do not seem to be sensitive to the estimation technique, the estimates obtained under the three-stage least squares technique are less precise than those based on the SUR technique.

[14] Interestingly, the parameter estimates were not significantly affected by using the capital stock net of the truncated geometric depreciation as opposed to the estimate using a delayed depreciation scheme. See Chapter 3 for a discussion of the two different estimation techniques.

Table 8.3 Non-parametric productivity growth measures of Canadian manufacturing industries, 1961-1995							
	Average annual growth rate (%)				Standard deviation		
	1961-1995	1961-1973	1973-1995	Pre-1973 to post-1973 gap	1961-1995	1961-1973	1973-1995
Food and Beverages	0.35	0.68	0.17	0.51	0.86	0.67	0.90
Tobacco	0.68	0.94	0.54	0.40	3.37	2.16	3.83
Textile	1.47	1.82	1.28	0.54	2.49	2.78	2.30
Clothing	0.88	1.09	0.76	0.33	1.73	1.27	1.94
Wood and Lumber	0.81	1.06	0.67	0.39	2.43	1.43	2.79
Furniture and Fixtures	0.55	1.83	–0.13	1.96	3.30	2.14	3.62
Paper and Allied Products	0.10	0.37	–0.05	0.42	2.89	1.95	3.31
Printing and Publishing	–0.03	0.66	–0.40	1.07	2.32	1.44	2.69
Chemical and Allied Products	1.22	1.85	0.88	0.96	2.52	1.92	2.79
Refineries	0.48	0.88	0.26	0.62	1.72	2.35	1.32
Rubber and Plastic Products	1.16	2.05	0.68	1.36	2.98	2.58	3.10
Leather	0.65	0.63	0.66	–0.03	1.91	1.32	2.14
Non-metallic Mineral	0.87	2.23	0.13	2.11	3.49	3.44	3.31
Primary Metal	0.55	0.70	0.47	0.22	2.33	1.43	2.66
Fabricated Metal	0.89	1.41	0.60	0.81	1.99	2.08	1.93
Machinery	1.36	1.05	1.52	–0.47	3.27	2.81	3.48
Electrical and Electronic	1.41	2.38	0.88	1.50	2.80	3.19	2.58
Transportation Equipment	1.22	2.26	0.66	1.60	2.44	2.66	2.16
Total Manufacturing	**0.82**	**1.31**	**0.53**	**0.79**	**2.18**	**1.86**	**2.24**

The average annual growth rates reveal a post-1973 productivity growth slowdown owing to the joint effect of the oil shocks and the two major recessions of the early 1980s and 1990s. The industries that show negative growth rates in the post-1973 period are printing and publishing, paper and allied products and furniture and fixtures. With a cost share of energy of 7% over the 1961 to 1995 period, the last is the most energy-intensive industry of the Canadian manufacturing sector and should have been most affected by energy price shocks. It appears that certain other industries were also affected by the energy shock in the mid-1970s, including fabricated metal products, chemical and allied products, and rubber and plastic products, most of which are energy intensive. These industries, however, are also those that experience intense international competition. Interestingly, the only industry to exhibit a substantial increase in productivity growth over this period was machinery.

The traditional productivity growth indices are procyclical, with, for example, declines appearing in most industries around the late 1960s, mid-1970s, early and late 1980s, and early 1990s. A measure of the extent of the magnitude of these fluctuations is the standard deviation, which indicates the variability of these productivity growth rates around the mean for each industry. These measures are rather large for both durable and non-durable goods industries, with a significant increase experienced over the post-1973 period.

The observed fluctuations are systematically related to the business cycle. When this productivity growth measure is correlated with Statistics Canada's published capacity utilization measure, the correlations are positive and statistically significant.

The size of these fluctuations suggests that the underlying series have not been purged of cyclicality, that unused capacity utilization has not been fully considered in the standard estimates. It is possible to argue that technical progress occurs more or less continuously and that fluctuations of the magnitude demonstrated by existing measures are

Table 8.4 Non-parametric and parametric productivity growth measures of Canadian manufacturing industries without adjustment for scale economies, fixity and price-cost margins, ε_{Ct}, 1961-1995

	Primal non-parametric	Dual parametric	Parametric lower bound[1]	Parametric upper bound[1]
		average annual %		
Food and Beverages	0.35	0.31	0.26	0.36
Tobacco	0.68	0.61	0.46	0.76
Textile	1.47	1.36	1.15	1.57
Clothing	0.88	0.85	0.67	1.03
Wood and Lumber	0.81	0.79	0.59	0.99
Furniture and Fixtures	0.55	0.51	0.40	0.62
Paper and Allied Products	0.10	0.13	0.10	0.16
Printing and Publishing	-0.03	0.01	0.01	0.01
Chemical and Allied Products	1.22	1.13	0.96	1.30
Refineries	0.48	0.51	0.40	0.62
Rubber	1.16	1.09	0.83	1.35
Leather	0.65	0.63	0.52	0.74
Non-metallic Mineral	0.87	0.84	0.74	0.94
Primary Metal	0.55	0.52	0.39	0.65
Fabricated Metal	0.89	0.86	0.74	0.98
Machinery	1.36	1.33	1.15	1.51
Electrical and Electronic	1.41	1.36	1.10	1.62
Transportation Equipment	1.22	1.17	0.97	1.37
Total Manufacturing	**0.82**	**0.78**	**0.64**	**0.92**

Note: 1. 95% confidence intervals.

not credible. Of course, there are opposing arguments that suggest that cyclical variations of some sort should always be found in the data, since technology is absorbed more slowly in recessions because investment is so dependent on the internal flow of funds to firms and these are procyclical.

In the end, the issue is not whether there should be any fluctuations in productivity growth, but whether the size of the fluctuations that are characteristic of standard measures is reasonable. In the succeeding sections, we ask whether an alternate methodology that directly takes into account capacity utilization produces cycles in productivity growth estimates that are less dramatic than existing estimates.

8.4.2 The parametric productivity growth measure

1) The standard measure

In order to examine the effects of economies of scale and fixity, we make use of the dual cost function and estimate multifactor productivity using multivariate analysis and the assumption of no scale economies and no capital fixity. The estimates produced are listed in Table 8.4 and compared with the standard non-parametric estimates produced by the primal approach.

Overall, the two estimates are quite similar, though not identical. The non-parametric estimate derived from the primal approach has a mean value over the period 1961-1995 of 0.82, while the parametric estimate, using the dual approach, has a value of 0.78, an estimate that is 95% of the former. At the two-digit industry level, the differences range from 2 to 11 percentage points, with most of the parametric estimates being above 92% of the value yielded by the non-parametric approach.

Table 8.5 Average annual cost elasticities, Canadian manufacturing industries, 1961-1995

	$\varepsilon_{CY}\left[= CU \cdot \varepsilon^{L}_{CY}\right]$				
	1961-1973	1973-1995	1961-1995	Confidence intervals for the 1961 to 1995 period[1]	
				Lower bound	Upper bound
Food and Beverages	.813	.753	.774	0.687	0.861
Tobacco	.763	.683	.713	0.602	0.824
Textile	.781	.710	.736	0.656	0.816
Clothing	.710	.710	.712	0.624	0.800
Wood and Lumber	.700	.685	.691	0.562	0.820
Furniture and Fixtures	.756	.700	.723	0.599	0.847
Paper and Allied Products	.733	.651	.682	0.611	0.753
Printing and Publishing	.794	.739	.758	0.675	0.841
Chemical and Allied Products	.717	.608	.641	0.584	0.698
Refineries	.792	.810	.804	0.708	0.900
Rubber	.863	.798	.824	0.689	0.959
Leather	.782	.760	.771	0.675	0.867
Non-metallic Mineral	.782	.705	.735	0.659	0.811
Primary Metal	.825	.765	.788	0.682	0.894
Fabricated Metal	.909	.886	.895	0.755	1.035
Machinery	.852	.737	.779	0.714	0.844
Electrical and Electronic	.893	.739	.793	0.673	0.913
Transport Equipment	.871	.753	.796	0.725	0.867
Total Manufacturing	**.819**	**.738**	**.767**	**0.678**	**0.859**

Note: 1. 95% confidence intervals.

The parametric estimation technique lends itself more readily than the non-parametric approach to the construction of confidence intervals around the point estimate. Using the standard errors of the parameter estimates, a 95% confidence interval for the parametric estimate extends from .64 to .92—a value of about .30 percentage points.

The size of the corrections that can be made to the parametric estimates as a result of scale economies and capital fixity will now be considered in turn.

2) On scale economies and capacity utilization

a) Analysis of the results

The short-run cost elasticity (ε_{CY}) is related to both the size of long-run returns to scale (scale economies ε^{L}_{CY}) and the impact of short-run fixities (as manifested by the degree of capacity not utilized $CU \equiv \frac{C^*}{C}$). As outlined previously, $\varepsilon_{CY} = CU \cdot \varepsilon^{L}_{CY}$.

Using our model, the short-run cost elasticity and capacity utilization were estimated separately and the long-run elasticity was derived therefrom. The measure of short-run cost elasticity and the capacity utilization are presented as annual averages in Tables 8.5 and 8.6, respectively.

The measured short-run cost elasticity ε_{CY} is presented in terms of annual averages in Table 8.5, and in full index form in Appendix Table 8.2A. These measures suggest short-run scale economies exist and are quite substantial in a number of industries. On average, for the 1961 to 1995 period, the short-run scale economies are about 1.30 (the inverse of the short-run cost elasticity with a 95% confidence interval ranging from 1.16 to 1.47).

Table 8.6 Capacity utilization, Canadian manufacturing industries, 1961-1995					
	$CU = \left(\frac{C^*}{C}\right)$				
	1961-1973	1973-1995	1961-1995	Confidence intervals for the 961-1995 period[1]	
				Lower bound	Upper bound
			annual average		
Food and Beverages	.995	.941	.968	0.834	1.102
Tobacco	.981	.935	.958	0.791	1.125
Textile	1.069	.901	.985	0.851	1.119
Clothing	.973	.894	.934	0.805	1.063
Wood and Lumber	.901	.996	.949	0.748	1.150
Furniture and Fixtures	.891	.845	.868	0.704	1.032
Paper	.954	.912	.933	0.818	1.048
Printing and Publishing	.945	.871	.908	0.792	1.024
Chemical	1.049	.912	.981	0.881	1.081
Refineries	.998	.945	.972	0.838	1.106
Rubber	.912	.868	.891	0.726	1.056
Leather	.962	.871	.917	0.781	1.053
Non-metallic Mineral	.951	.842	.897	0.817	0.977
Primary Metals	.971	.873	.922	0.782	1.062
Fabricated Metal	.975	.908	.942	0.769	1.115
Machinery	.957	.912	.935	0.837	1.033
Electrical and Electronic Products	.971	.981	.976	0.809	1.143
Transportation Equipment	.986	.924	.986	0.882	1.090
Total Manufacturing	**.969**	**.907**	**.940**	**0.826**	**1.088**

Note: 1. 95% confidence intervals.

Short-run scale economies increase over time,[15] especially in industries that tend to be more capital intensive and have experienced productivity growth stagnation, such as chemicals, primary metals, and pulp and paper.

The average value of capacity utilization for the entire period from 1961 to 1995, reported in Table 8.6, is 94%, with a 95% confidence interval from 83% to 109%.[16] The point estimates of capacity utilization are below 100% virtually everywhere throughout the time period. The levels are less than 90% in the furniture, rubber products and non-metallic mineral products industries, indicating that the cost consequences of short-run excess capacity are often greater than 10%.

Capacity utilization has been declining in every industry but wood and lumber and electrical and electronic products. The excess capacity has been driven primarily, especially since 1973, by a low shadow value of capital relative to its market price; in most industries a decline in the $\frac{w_K}{p}$ ratio has occurred since 1973. The estimated capacity utilization has decreased between the pre- and post-1973 period. A trend regression finds significant declines over time.

Capacity utilization is procyclical by definition. Similarly, if scale economies exist, output expansion from upward swings in the cycle cause long-run average cost declines, so this component of ε_{CY} may also be procyclical. The procyclicality of the

[15] A trend regression model finds a significant upward movement in the scale elasticity over the time period.

[16] Earlier, we rejected the hypothesis that utilization was 100% when we pooled observations for all regressions. When we look at each industry individually, we cannot reject the null hypothesis that capacity utilization, on average, is 100%.

Table 8.7 Long-run cost elasticity, Canadian manufacturing industries, 1961-1995

	$\left(\varepsilon_{CY}^{L} = \frac{MC \cdot Y}{C^*}\right)$				
	1961-1973	1973-1995	1961-1995	Confidence intervals for the 1961-1995 period[1]	
				Lower bound	Upper bound
			annual average		
Food and Beverages	0.817	0.800	0.800	0.70	0.93
Tobacco	0.777	0.731	0.744	0.63	0.90
Textile	0.731	0.788	0.748	0.66	0.86
Clothing	0.730	0.794	0.763	0.67	0.88
Wood and Lumber	0.776	0.687	0.728	0.60	0.92
Furniture and Fixtures	0.849	0.828	0.833	0.70	1.03
Paper	0.769	0.714	0.731	0.65	0.83
Printing and Publishing	0.840	0.848	0.835	0.74	0.96
Chemical	0.683	0.666	0.654	0.59	0.73
Refineries	0.794	0.857	0.828	0.73	0.96
Rubber	0.946	0.919	0.925	0.78	1.13
Leather	0.813	0.873	0.842	0.73	0.99
Non-metallic Mineral	0.822	0.837	0.819	0.75	0.90
Primary Metal	0.850	0.877	0.854	0.74	1.01
Fabricated Metal	0.932	0.975	0.950	0.80	1.16
Machinery	0.890	0.807	0.833	0.75	0.93
Electrical and Electronic	0.919	0.753	0.813	0.69	0.98
Transportation Equipment	0.883	0.764	0.807	0.73	0.90
Total Manufacturing	**0.837**	**0.792**	**0.804**	**0.71**	**0.93**

Note: 1. Confidence intervals derived by dividing short-run cost elasticity by the 95% confidence intervals for capacity utilization.

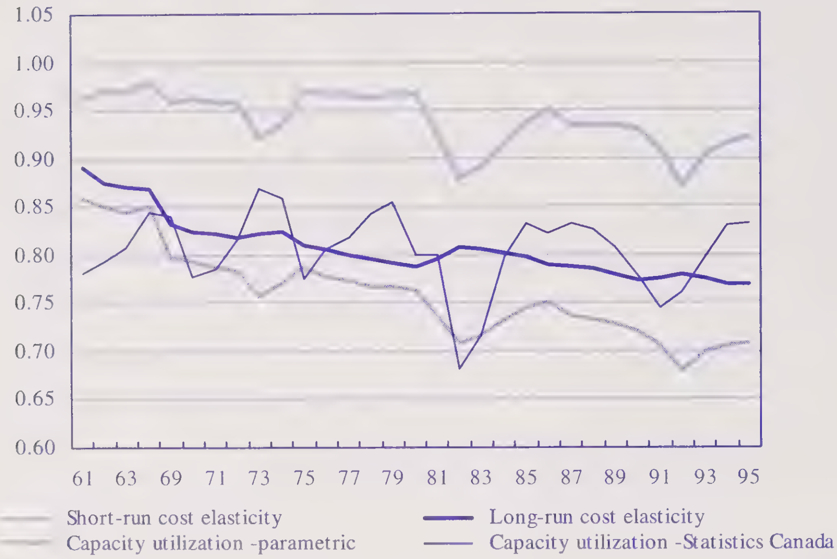
ε_{CY} measure is evident from Appendix Table 8.2A, where, for example, declines are evident for most industries in the downturns of 1970-1973, 1981-1982 and 1990-1992. To a large extent cyclical movements in ε_{CY} are driven by fluctuations in capacity utilization.

The estimates of the long-run returns to scale that are derived from the short-run elasticity and the rate of capacity utilization are provided in Table 8.7. The long-run average cost elasticity of the manufacturing sector as a whole between 1961 and 1995 is 0.80, suggesting that returns to scale are around 20%. These estimates, however, are subject to rather large confidence intervals. If we use the point estimates of the short-run cost elasticity and the upper and lower bounds for our estimate of capacity utilization, the long-run scale estimate ranges from 9% to 41%. Nevertheless, this range includes other estimates of the scale elasticity in the Canadian manufacturing sector. Baldwin and Gorecki (1986) use micro-data of manufacturing plants to estimate scale elasticities and report a figure of about 16%, an estimate not far removed from the point estimate derived here from time series data.

Both the estimate of capacity utilization CU and the estimate of long-run cost elasticity ε_{CY}^{L} decline from the first period (1961 to 1973) to the second period (1973 to 1995) and drive the declining short-run cost elasticity ε_{CY}. In particular, long-run returns to scale (the inverse of ε_{CY}^{L}) are substantial and increasing, especially in durable goods industries such as machinery, electrical and electronic products, and transportation equipment and in non-durable goods industries such as wood and lumber.

Figure 8.1 displays the long-run and short-run cost elasticities along with two different capacity utilization estimates. The first estimate of capacity utilization is generated from our parametric framework and the second, produced by Statistics Canada, is based on the ratio of actual to potential output.[17] Figure 8.1 indicates that while these alternative measures of capacity utilization display different levels, they both reveal a downward trend over the 1961 to 1995 period. With a steeper decline, the parametric measure of capacity utilization suggests that the manufacturing sector has not recovered the level of capacity of the golden era of economic growth (the pre-1973 period).

Figure 8.1 Cost elasticity and capacity utilization, manufacturing sector, 1961-1995



It is also noteworthy that long-run scale economies (the inverse of the long-run cost elasticity) increase rather smoothly (Figure 8.1). This confirms, at the sectoral level, what has already been observed at the industry level: to a large extent cyclical movements in ε_{CY} are driven by utilization fluctuations.

b) Implications of scale economies on price-marginal cost markups and the adjustment factor

The evidence that there are scale economies in the Canadian manufacturing sector is critical since it implies the existence of a price-marginal cost markup, which has implications for the accuracy of the standard productivity measures. The existence of both scale economies and price-marginal costs markups may lead to bias in the measure of the output share that is used in the measurement of the standard productivity growth (see equation (1)). It is, therefore, useful to estimate the size of markups implicitly being earned in the manufacturing sector.

Markups

The markups that we estimate are presented in Table 8.8 in terms of annual averages, and in Appendix Table 8.3A in their full form. The results, consistent with those found by Morrison (1994), indicate that, for the 1961 to 1995 period, the markups are about 29% with a confidence interval ranging from 16% to 39%.

[17] Statistics Canada's estimates of capacity utilization are built from surveyed estimates of capacity utilization rates. Capacity utilization is defined as the ratio of existing output to maximum or capacity output. See Statistics Canada (1994) p. 53.

Table 8.8 Average annual markups, Canadian manufacturing industries, 1961-1995

	$\frac{P}{MC}\left[=\frac{1}{(1+\varepsilon_{PY})}\right]$				
	1961-1973	1973-1995	1961-1995	Confidence intervals for the 1961-1995 period[1]	
				Lower bound	Upper bound
			%		
Food and Beverages	1.258	1.213	1.280	1.151	1.365
Tobacco	1.361	1.313	1.390	1.192	1.530
Textile	1.248	1.224	1.264	1.156	1.340
Clothing	1.281	1.292	1.276	1.164	1.398
Wood and Lumber	1.441	1.449	1.440	1.216	1.666
Furniture and Fixtures	1.200	1.179	1.212	1.024	1.376
Paper	1.444	1.446	1.445	1.329	1.559
Printing and Publishing	1.206	1.134	1.247	1.105	1.307
Chemical	1.612	1.543	1.661	1.521	1.703
Refineries	1.205	1.223	1.200	1.062	1.348
Rubber	1.226	1.165	1.261	1.072	1.380
Leather	1.227	1.241	1.220	1.107	1.347
Non-metallic Mineral	1.165	1.168	1.166	1.067	1.263
Primary Metal	1.228	1.268	1.208	1.104	1.352
Fabricated Metal	1.161	1.175	1.156	1.003	1.319
Machinery	1.397	1.265	1.471	1.323	1.471
Electrical and Electronic	1.309	1.165	1.388	1.136	1.482
Transportation Equipment	1.118	1.151	1.211	1.059	1.177
Total Manufacturing	**1.291**	**1.254**	**1.313**	**1.163**	**1.389**

Note: 1. 95% confidence intervals

A secular increase in the price-marginal cost markup is evident,[18] although significant year-to-year variations occur. This tendency is more apparent from the year-to-year changes appearing in Appendix Table 8.3A than from the overall averages. The only industries experiencing a clear downward trend in markups are primary metals, fabricated metal products, clothing, wood and lumber, leather products and refineries. This is consistent with intensifying international competition in the apparel, lumber and primary metal markets. In the petroleum refining industry, it has probably arisen from an increase in crude oil prices relative to international refined product prices, which has provided downward pressures on domestic profit margins. Some other industries facing increasing international competition, such as pulp and paper and non-metallic mineral products, have had quite constant margins. Interestingly, markups in high-technology industries such as electrical and electronic products, machinery, transportation equipment and chemical products increased between 1961-1973 and 1973-1995.

The estimate of the price-marginal cost markup is generally compatible with the estimates of the long-run elasticity of scale. We can see this by making use of our simple primal estimate derived from the Cobb-Douglas production function used in the section on the scale economies. If the marginal revenue is adjusted downward by about 28% for both the labour and capital weight, as is required by this estimate of the markup, the sum of the two coefficients would in effect yield an estimate of the long-run scale economies of about 1.28. The estimate of the long-run scale economies derived from the non-parametric technique is 1.23%.

[18] Once more, a trend regression is significant.

Table 8.9 Full adjustment factor, Canadian manufacturing industries, 1961-1995					
	ADJ			Confidence intervals for the 1961-1995 period[1]	
	1961-1973	1973-1995	1961-1995	Lower bound	Upper bound
	average annual level				
Food and Beverages	0.974	0.986	0.964	0.794	1.174
Tobacco	0.970	1.002	0.950	0.715	1.254
Textile	0.919	0.956	0.897	0.763	1.099
Clothing	0.913	0.918	0.906	0.722	1.118
Wood and Lumber	0.996	1.013	0.986	0.681	1.366
Furniture and Fixtures	0.868	0.892	0.848	0.614	1.170
Paper	0.985	1.060	0.941	0.811	1.169
Printing and Publishing	0.914	0.900	0.922	0.740	1.098
Chemical	1.034	1.106	1.010	0.882	1.192
Refineries	0.969	0.969	0.972	0.769	1.194
Rubber	1.009	1.005	1.006	0.739	1.325
Leather	0.946	0.971	0.927	0.742	1.171
Non-metallic Mineral	0.856	0.913	0.822	0.704	1.023
Primary Metal	0.967	1.046	0.924	0.751	1.203
Fabricated Metal	1.039	1.068	1.024	0.762	1.358
Machinery	1.088	1.077	1.084	0.939	1.236
Electrical and Electronic	1.038	1.040	1.025	0.761	1.349
Transportation Equipment	0.945	1.002	0.912	0.773	1.024
Total Manufacturing	**0.974**	**0.996**	**0.950**	**0.783**	**1.184**

Note: 1. 95% confidence intervals.

Output share of the standard productivity framework

Recall that the $ADJ = \frac{\varepsilon_{CY}}{(1+\varepsilon_{PY})}$ variable shown in (3) measures the extent to which nominal output is close to economic costs and, accordingly, if economic profits are equal to zero. It provides an indication of the accuracy of the output share used in the standard productivity framework. With $ADJ \neq 1$, it follows that the standard productivity framework uses a measured output share that encompasses market returns that are not related to just improvements in efficiency. However, it may be the case that the output share constitutes a reasonable approximation of the cost share as counteracting effects may arise between the cost elasticity and markups.

The results, reported in Figure 8.2, show that for the manufacturing sector ADJ was close to unity during the pre-1973 period and it declined slightly thereafter. For the 1961 to 1995 period, ADJ averaged 0.97. But this estimate is subject to a high degree of uncertainty as evidenced by its large confidence interval (from 0.78 to 1.19). In addition, there is a wide discrepancy between revenue and costs at the individual industry level (Table 8.9). These findings reflect the fact that revenue (and therefore the revenue share) appearing in (1) embodies returns to all characteristics of the production process. In contrast, costs C (and thus the cost shares) include only ex ante returns to inputs, so (2) captures the effect of technical change independent of these other effects.

8.5 Correcting the productivity measure for scale and fixity

The productivity growth rates that allow for economies of scale and capital fixity are reported in Table 8.10. On average, the corrected value is 0.60 over the period 1961 to 1995, while the uncorrected value was 0.78 (Table 8.4) for a reduction of 0.18 percentage points.

Figure 8.2 Markups, capacity utilization and short-run cost elasticity, manufacturing sector, 1961-1995

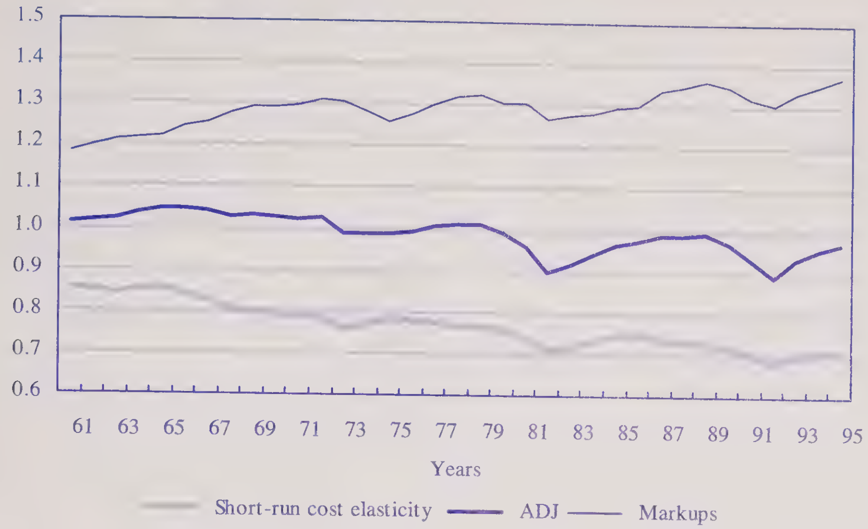
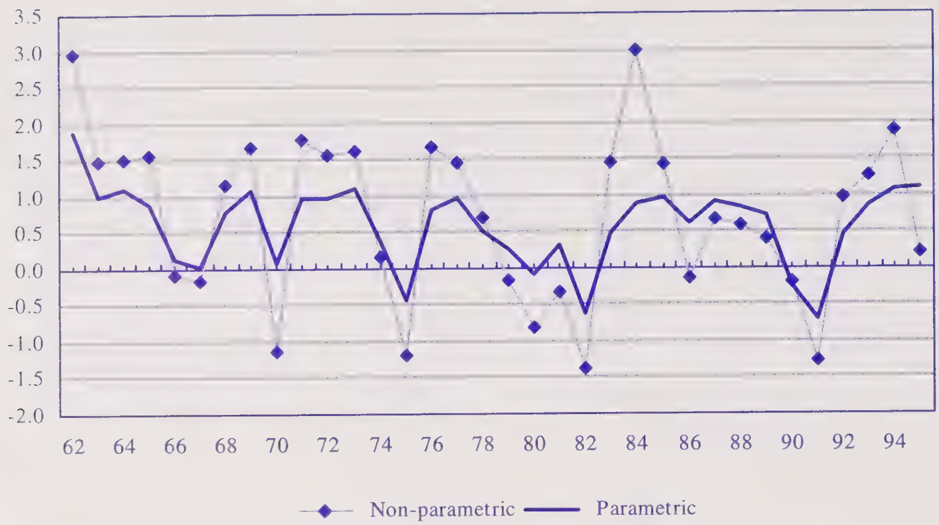


Table 8.10 Parametric productivity growth measures of Canadian manufacturing industries, 1961-1995

	Average annual growth rate				Standard deviation		
	1961-1995	1961-1973	1973-1995	Pre-1973 to post-1973 gap	1961-1995	1961-1973	1973-1995
Food and Beverages	0.27	0.44	0.09	0.355	0.4	0.4	0.3
Tobacco	0.41	0.88	0.20	0.678	2.4	1.4	2.8
Textile	0.84	1.12	0.68	0.443	1.1	1.4	0.9
Clothing	0.58	0.95	0.44	0.515	1.5	1.0	1.7
Wood and Lumber	0.52	0.84	0.33	0.510	1.4	1.1	1.5
Furniture and Fixtures	0.25	0.63	0.08	0.546	1.6	0.7	1.9
Paper	0.25	0.30	0.26	0.042	1.2	0.6	1.4
Printing and Publishing	0.18	0.76	0.02	0.742	1.5	1.3	1.7
Chemical	1.10	1.10	1.14	-0.042	1.6	0.9	1.9
Refineries	0.57	0.87	0.48	0.399	1.2	1.6	1.0
Rubber	0.68	1.24	0.50	0.743	1.7	1.4	1.8
Leather	0.68	0.64	0.69	-0.047	1.1	1.0	1.1
Non-metallic Mineral	0.86	1.69	0.45	1.240	1.7	1.9	1.5
Primary Metal	0.45	0.65	0.36	0.284	1.1	1.0	1.2
Fabricated Metal	0.59	0.67	0.58	0.096	0.9	0.7	0.9
Machinery	0.98	1.21	0.93	0.281	1.8	1.8	1.8
Electrical and Electronic	1.09	1.32	1.03	0.290	1.6	1.2	1.8
Transportation Equipment	0.98	1.14	0.91	0.231	1.1	0.8	1.2
Total Manufacturing	**0.60**	**0.82**	**0.49**	**0.33**	**1.00**	**0.89**	**1.03**

Figure 8.3 Alternate estimates of multifactor productivity, manufacturing sector



It is important to note that the precision of this point estimate is subject to substantial uncertainty. Our correction is derived from an estimate of capacity utilization of 0.94 with a confidence interval stretching from 0.82 to 1.088. In other words, our estimate cannot rule out that capacity utilization on average was not different from 1. It is also derived from a long-run elasticity of 1.24 but with confidence intervals for this estimate stretching from 1.08 to 1.41. If we choose an estimate of capacity utilization of 1 and an estimate of the long-run returns to scale of no more than 8%, our correction factor would be less than 0.02% or no more than 5% of the original estimate.

It is also useful to consider differences in the time path of the corrected parametric estimates and the uncorrected estimates. For this purpose, we compare the differences in the parametric dual to the non-parametric primal estimates. A comparison of the indices in Tables 8.3 and 8.10 shows larger differences between the corrected parametric and uncorrected non-parametric estimates of productivity growth during the pre-1973 period. For example, for total manufacturing, unadjusted growth rates for the periods 1961-1973 and 1973-1995 are 1.3% and 0.5%, respectively. The corresponding adjusted values are 0.82% and 0.49%, respectively. Scale economies accounted for 37% of total productivity growth in the first period, but only 7% in the second period. After allowance has been made for scale economies, there is less of a productivity growth slowdown than is shown by the traditional estimates—though it has not disappeared completely. Thus, a partial explanation of the post-1973 slowdown arises from changes in the importance of scale economies.

The revised productivity measures have somewhat smaller secular and cyclical fluctuations. The standard deviations of the revised productivity growth rates for the manufacturing sector as a whole over the periods 1961-1995, 1961-1973 and 1973-1995 were only 50%, 33%, and 44%, respectively, of the standard deviations of the original growth rates. This tendency to 'smooth' the productivity growth measure is corroborated by an examination of the year-to-year fluctuations reported in Appendix Table 8.4A, and in Figure 8.3 of ε_{Yt} (traditionally measured) and $\varepsilon_{Ct}^{\text{full}}$ for total manufacturing.

8.6 Conclusion

This chapter has examined the impact of relaxing several standard assumptions about economies of scale, instantaneous capacity adjustment and competitive pricing that are embedded in the estimation techniques used for productivity measures.

Assumptions are required in the measurement process to facilitate estimation—just as they are in developing theory to provide simple abstractions. They are meaningful in theory if they distil a complex problem into a representation that captures the essence of the process that is being examined. They are meaningful for the measurement process if they do the same.

It is recognized that not all markets are perfectly competitive. Nor are all markets characterized by constant returns to scale. Moreover, capacity utilization is not 100% at all times.

There are two issues that statisticians must address. First, does the relaxation of these assumptions make much of a difference to the estimates that are produced? Second, can we place much faith in the precision of the estimates of these complex phenomena?

This chapter provides evidence derived from an experiment that asks whether accurate estimates can be made of the component of productivity growth that is due to the exploitation of economies of scale and capacity utilization. It has done so by asking what fraction of the measures that are normally used to represent productivity growth can be attributed to these components.

Our research has provided a point estimate that up to 20% of productivity growth is due to the exploitation of economies of scale and fixity of capital. However, it should be noted that these measures are not very precise. The size of the bounds that accompany these estimates means we should tread carefully in assigning a specific contribution to economies of scale in the productivity growth.

There is another reason to proceed cautiously in this area. It is not clear that the exploitation of scale economies and disembodied technical progress can really be separated. A firm can rarely simply take advantage of scale economies by scaling up the production process. To do so often requires innovation and technical breakthroughs. For example, there are a number of production processes that take advantage of the scale economies associated with a production process involving a cylindrical shape—pipelines, chemical plants, petroleum refineries. Each of these processes involves a particular type of scale economy—that is, a cylinder's circumference, which has to be constructed out of materials, increases less quickly as it is expanded than does the volume contained therein. As such, volume or quantity produced increases faster than the input materials required. As plants grow larger, declining average costs result. However, taking advantage of these economies often requires technological breakthroughs. For example, the jumbo jet, which involved these types of economies, needed better engines. The Bessemer steel furnace required special fans to blow oxygen through molten metal, and petroleum refineries required new engineering techniques to master mass distillation processes.

This does not mean that productivity growth does not emerge from the exploitation of economies of scale. Rather it means that it is probably inappropriate to say that the decomposition we have performed here precisely isolates technical change from the

exploitation of scale economies. A good part of the latter is the result of technical improvements in production processes. At best, we can say that we have divided the technical progress component into two items—one that is related to the exploitation of economies of scale and one that is separate from it.

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Appendix Table 8.1A Non parametric annual multifactor productivity growth rates of the Canadian manufacturing sector

Year	Food and Beverage	Tobacco	Textiles	Clothing	Wood and Lumber	Furnitures	Pulp and Paper	Printing	Chemical Products	Refineries
					Percentage					
1962	1.47	-0.84	6.25	2.47	2.48	1.73	0.04	2.20	3.42	5.96
1963	0.57	3.28	2.89	1.71	3.65	2.99	1.33	0.31	2.53	0.69
1964	0.45	2.26	0.28	-0.15	1.42	0.58	1.76	-0.52	3.61	2.07
1965	1.36	1.78	-1.60	1.09	-0.22	4.28	-1.23	-0.08	1.47	1.48
1966	0.98	-3.04	-1.63	0.87	-0.51	1.30	-1.25	0.34	0.85	1.17
1967	0.19	-2.15	-0.45	-1.51	0.08	0.57	-3.48	0.13	-0.82	-4.07
1968	-0.51	-0.89	5.17	1.60	3.20	0.86	0.87	0.19	1.34	1.19
1969	0.38	1.55	3.78	0.22	1.83	2.96	2.62	0.67	2.77	-1.22
1970	0.17	1.83	-1.19	-0.12	0.29	-2.94	-0.78	-1.67	-2.46	0.35
1971	1.99	3.76	3.22	2.56	0.80	1.39	-0.67	0.28	3.01	1.15
1972	0.50	2.31	4.43	2.07	-0.06	5.48	2.75	2.87	2.59	-0.30
1973	0.65	1.73	1.09	2.36	-0.09	2.98	2.70	3.35	4.06	2.44
1974	-0.40	3.14	0.56	0.49	-1.60	-7.66	1.54	0.03	-0.16	-2.55
1975	-1.55	-1.54	1.22	1.83	-1.95	-1.83	-9.99	1.46	-6.24	-0.13
1976	2.51	-0.90	2.08	2.33	4.61	4.62	6.18	5.05	2.75	-0.02
1977	1.24	4.63	4.01	2.52	3.15	0.79	0.19	3.01	1.34	3.31
1978	-0.08	-2.04	3.86	3.23	-1.26	3.57	3.32	2.87	3.40	-1.68
1979	0.05	0.73	3.11	2.41	-0.99	-2.24	-0.57	-1.30	-0.40	-1.87
1980	-0.94	0.73	-0.12	-1.17	2.81	-1.41	0.36	-0.02	-3.34	0.80
1981	-0.54	-0.84	1.42	0.10	0.60	1.50	-2.29	-0.41	2.69	1.46
1982	-0.19	0.38	-3.74	-2.99	-1.84	-7.66	-3.80	-3.58	-2.38	0.26
1983	-0.19	-1.26	7.48	-0.30	8.12	4.79	4.41	0.87	3.43	0.74
1984	0.60	-1.14	0.34	3.18	4.03	1.62	1.46	2.83	3.75	0.15
1985	0.71	-2.14	1.03	1.07	2.90	1.56	0.59	0.15	2.62	0.49
1986	-0.41	-2.52	3.41	1.77	0.08	-0.01	0.36	-0.40	2.36	0.04
1987	0.48	7.56	0.66	2.67	4.72	-3.99	0.74	-1.85	1.91	1.62
1988	-0.11	3.61	-1.54	-3.80	-1.40	-2.06	-1.21	-1.08	1.70	0.47
1989	-1.15	2.27	0.51	0.66	-1.09	-0.67	-3.61	-1.19	2.60	1.29
1990	1.02	-4.18	-1.58	1.00	-1.94	1.57	-2.90	-0.68	-0.82	0.43
1991	0.46	0.69	-1.39	-1.42	-1.49	-4.44	-1.22	-7.57	-4.16	-0.29
1992	0.25	-1.89	1.54	1.08	1.59	5.94	2.20	-2.57	0.18	0.28
1993	-0.16	-4.92	2.15	-1.56	0.06	1.24	2.54	-3.19	2.66	-0.96
1994	1.17	12.43	2.69	2.56	-1.63	2.69	1.92	-0.44	3.05	1.18
1995	1.11	0.74	1.10	1.53	-1.80	0.55	-0.13	-0.10	3.32	0.97
					Average					
1961-95	0.36	0.74	1.50	0.89	0.84	0.61	0.14	0.00	1.25	0.50
1961-73	0.68	0.96	1.85	1.10	1.07	1.85	0.39	0.67	1.86	0.91
1973-95	0.20	0.66	1.30	0.85	0.68	0.06	0.12	-0.21	1.06	0.37
					Standard Deviation					
1961-95	0.86	3.37	2.49	1.73	2.43	3.30	2.89	2.32	2.52	1.72
1961-73	3.61	0.67	2.16	2.78	1.27	1.43	2.14	1.95	1.44	1.92
1973-95	6.78	0.90	3.83	2.30	1.94	2.79	3.62	3.31	2.69	2.79

Appendix Table 8.1A Non parametric annual multifactor productivity growth rates of the Canadian manufacturing sector (continued)

Year	Rubber and Plastic Products	Leather Products	Non-Metallic Mineral Products	Primary Metals	Fabricated Metal Products	Commercial and Industrial Machinery	Electrical and Electronic Products	Trans-portation Equipment	Manu-facturing
					Percentage				
1962	8.56	3.01	6.85	2.93	4.68	5.58	7.53	3.97	2.97
1963	2.17	1.29	1.45	1.98	2.00	0.43	1.35	3.70	1.49
1964	2.44	2.73	3.70	1.65	3.98	4.80	4.35	0.66	1.51
1965	1.22	-0.22	1.60	1.25	3.08	0.97	2.75	3.36	1.56
1966	1.76	-0.92	0.40	-0.40	-0.64	2.18	-0.57	-1.47	-0.08
1967	-0.11	-0.64	-4.88	-1.49	-1.06	-2.58	-3.74	4.05	-0.15
1968	3.93	0.39	3.12	2.32	0.74	-0.25	2.68	2.02	1.15
1969	1.56	0.81	1.93	1.20	0.73	2.89	2.92	4.23	1.66
1970	-2.25	0.65	-1.76	-0.25	-2.34	-1.14	-1.68	-3.97	-1.12
1971	0.85	1.25	6.63	-1.26	1.75	-3.89	2.95	5.13	1.76
1972	1.66	-1.21	6.21	-0.31	1.62	1.26	5.45	3.05	1.56
1973	3.14	0.45	2.22	0.87	2.65	2.80	5.10	2.72	1.62
1974	-3.77	2.74	-0.31	-1.62	1.85	3.71	-0.37	1.40	0.16
1975	-3.91	1.35	-1.73	-1.82	-3.44	-2.32	-3.26	0.80	-1.19
1976	4.21	3.72	1.03	-0.62	1.97	1.52	4.39	1.42	1.67
1977	4.79	0.58	-0.74	4.09	0.15	1.43	3.34	0.76	1.45
1978	2.40	4.77	1.71	3.99	0.63	1.34	-1.20	0.66	0.71
1979	1.87	-2.80	0.15	-3.35	-0.94	4.74	5.11	-0.89	-0.15
1980	-3.02	0.70	-5.62	0.05	1.81	-0.56	2.21	-5.57	-0.82
1981	1.41	1.26	-1.45	-3.70	0.70	-1.74	0.41	1.49	-0.32
1982	-1.35	-0.95	-4.54	-3.19	-2.73	-4.65	-4.46	0.13	-1.38
1983	3.97	2.65	5.50	4.00	0.17	-1.31	-0.91	2.49	1.46
1984	5.08	2.56	5.00	6.27	2.59	10.84	2.64	4.47	2.98
1985	1.95	0.15	4.56	2.46	2.16	3.85	2.01	1.26	1.42
1986	-3.09	0.55	1.93	-2.52	2.67	2.38	0.43	-0.99	-0.14
1987	1.27	0.57	3.39	2.12	0.55	0.84	0.85	-0.73	0.67
1988	-3.09	-1.85	-0.81	-1.02	-0.65	3.51	-0.16	3.57	0.59
1989	-1.62	0.95	-2.27	1.77	0.50	0.10	3.00	1.18	0.40
1990	0.23	-2.71	-4.30	-0.01	0.58	0.49	-0.85	-0.61	-0.20
1991	-2.30	-2.37	-5.52	0.31	-2.54	-4.07	-2.15	-2.17	-1.26
1992	4.65	3.66	2.05	1.91	1.93	1.15	3.02	0.81	0.98
1993	4.00	-0.32	4.31	2.13	0.19	6.73	0.32	2.72	1.27
1994	3.59	1.97	2.46	-1.21	4.96	5.42	3.86	3.53	1.89
1995	-1.20	-2.23	-0.83	1.19	0.57	1.45	1.82	-0.72	0.22
					Average				
1961-95	1.21	0.66	0.92	0.58	0.91	1.41	1.45	1.25	0.72
1961-73	2.08	0.63	2.29	0.71	1.43	1.09	2.42	2.29	1.16
1973-95	0.84	0.67	0.27	0.53	0.71	1.64	1.09	0.77	0.52
					Standard Deviation				
1961-95	2.98	1.91	3.49	2.33	1.99	3.27	2.80	2.44	2.18
1961-73	2.35	2.58	1.32	3.44	1.43	2.08	2.81	3.19	2.67
1973-95	1.32	3.10	2.14	3.31	2.66	1.93	3.48	2.58	3.59

Appendix Table 8.2A Cost elasticity of Canadian manufacturing industries

Year	Food and Beverage	Tobacco	Textiles	Clothing	Wood and Lumber	Furnitures	Pulp and Paper	Printing	Chemical Products	Refineries
1961	0.83	0.82	0.83	0.76	0.70	0.82	0.81	0.88	0.83	0.81
1962	0.83	0.83	0.86	0.76	0.66	0.82	0.80	0.88	0.82	0.80
1963	0.82	0.82	0.86	0.74	0.64	0.82	0.78	0.85	0.80	0.80
1964	0.82	0.82	0.87	0.75	0.71	0.82	0.79	0.84	0.80	0.80
1965	0.82	0.81	0.84	0.76	0.73	0.81	0.78	0.82	0.80	0.80
1966	0.82	0.79	0.82	0.76	0.75	0.79	0.75	0.82	0.80	0.79
1967	0.81	0.78	0.79	0.74	0.72	0.77	0.75	0.80	0.76	0.79
1968	0.81	0.74	0.74	0.70	0.70	0.74	0.73	0.79	0.75	0.79
1969	0.81	0.71	0.71	0.68	0.69	0.73	0.69	0.75	0.68	0.79
1970	0.81	0.71	0.71	0.65	0.71	0.72	0.67	0.73	0.64	0.79
1971	0.81	0.71	0.71	0.65	0.72	0.71	0.69	0.73	0.62	0.79
1972	0.80	0.70	0.72	0.64	0.71	0.68	0.69	0.73	0.62	0.80
1973	0.79	0.69	0.72	0.64	0.66	0.61	0.71	0.73	0.61	0.79
1974	0.80	0.71	0.73	0.64	0.66	0.61	0.64	0.70	0.58	0.77
1975	0.80	0.70	0.70	0.72	0.69	0.67	0.64	0.73	0.61	0.78
1976	0.78	0.70	0.70	0.72	0.75	0.68	0.69	0.75	0.64	0.79
1977	0.77	0.70	0.72	0.72	0.77	0.74	0.69	0.77	0.63	0.79
1978	0.77	0.69	0.69	0.70	0.75	0.73	0.69	0.78	0.64	0.80
1979	0.77	0.70	0.69	0.70	0.76	0.74	0.70	0.81	0.64	0.81
1980	0.75	0.70	0.70	0.69	0.75	0.74	0.68	0.81	0.67	0.82
1981	0.73	0.69	0.70	0.69	0.67	0.67	0.69	0.81	0.67	0.83
1982	0.72	0.65	0.70	0.70	0.68	0.65	0.67	0.81	0.66	0.81
1983	0.73	0.66	0.71	0.71	0.70	0.67	0.59	0.76	0.56	0.79
1984	0.74	0.68	0.71	0.71	0.69	0.68	0.66	0.77	0.57	0.79
1985	0.74	0.67	0.68	0.71	0.69	0.69	0.67	0.79	0.60	0.82
1986	0.74	0.68	0.70	0.72	0.71	0.69	0.65	0.69	0.60	0.82
1987	0.75	0.68	0.69	0.72	0.71	0.69	0.64	0.71	0.62	0.84
1988	0.75	0.67	0.67	0.72	0.71	0.68	0.64	0.75	0.61	0.84
1989	0.75	0.69	0.71	0.73	0.71	0.69	0.64	0.74	0.62	0.85
1990	0.75	0.69	0.74	0.71	0.60	0.68	0.63	0.71	0.62	0.85
1991	0.74	0.68	0.75	0.69	0.58	0.68	0.62	0.70	0.60	0.81
1992	0.73	0.67	0.76	0.69	0.57	0.64	0.61	0.68	0.57	0.81
1993	0.75	0.67	0.73	0.75	0.62	0.69	0.60	0.61	0.54	0.78
1994	0.75	0.67	0.72	0.78	0.65	0.72	0.61	0.66	0.56	0.80
1995	0.75	0.67	0.70	0.80	0.67	0.73	0.62	0.74	0.57	0.81
					Average					
1961-95	0.77	0.71	0.74	0.71	0.69	0.71	0.68	0.76	0.64	0.80
1961-73	0.81	0.76	0.78	0.71	0.70	0.76	0.73	0.79	0.72	0.79
1973-95	0.75	0.68	0.71	0.71	0.68	0.68	0.65	0.74	0.61	0.81
					Standard Deviation					
1961-95	0.03	0.05	0.06	0.04	0.05	0.06	0.06	0.06	0.08	0.02
1961-73	0.01	0.06	0.07	0.05	0.03	0.07	0.06	0.06	0.09	0.01
1973-95	0.02	0.01	0.02	0.04	0.05	0.04	0.03	0.05	0.04	0.02

Appendix Table 8.2A Cost elasticity of Canadian manufacturing industries (continued)

Year	Rubber and Plastic Products	Leather Products	Non-Metallic Mineral Products	Primary Metals	Fabricated Metal Products	Commercial and Industrial Machinery	Electrical and Electronic Products	Trans-portation Equipment	Manu-facturing
1961	0.97	0.84	0.82	0.84	0.95	0.96	0.94	0.93	0.86
1962	0.96	0.83	0.83	0.84	0.95	0.93	0.92	0.91	0.85
1963	0.96	0.82	0.84	0.84	0.94	0.92	0.91	0.90	0.84
1964	0.94	0.83	0.84	0.87	0.94	0.91	0.92	0.90	0.85
1965	0.93	0.84	0.83	0.87	0.94	0.90	0.94	0.91	0.86
1966	0.90	0.84	0.80	0.86	0.92	0.86	0.94	0.87	0.84
1967	0.90	0.82	0.78	0.85	0.91	0.85	0.94	0.85	0.83
1968	0.83	0.77	0.75	0.81	0.88	0.81	0.88	0.85	0.80
1969	0.80	0.74	0.75	0.80	0.88	0.78	0.85	0.89	0.80
1970	0.77	0.74	0.75	0.80	0.89	0.79	0.84	0.87	0.79
1971	0.77	0.73	0.76	0.79	0.88	0.81	0.84	0.83	0.79
1972	0.75	0.73	0.73	0.79	0.88	0.80	0.85	0.83	0.78
1973	0.75	0.65	0.67	0.76	0.87	0.76	0.83	0.80	0.76
1974	0.80	0.65	0.70	0.77	0.87	0.76	0.85	0.83	0.77
1975	0.84	0.71	0.71	0.79	0.88	0.78	0.85	0.86	0.79
1976	0.83	0.79	0.72	0.79	0.87	0.76	0.82	0.83	0.78
1977	0.80	0.79	0.73	0.78	0.88	0.75	0.81	0.81	0.77
1978	0.78	0.82	0.73	0.78	0.88	0.75	0.80	0.79	0.77
1979	0.78	0.85	0.75	0.78	0.88	0.75	0.79	0.77	0.77
1980	0.77	0.84	0.76	0.79	0.89	0.72	0.77	0.78	0.76
1981	0.73	0.76	0.65	0.78	0.90	0.64	0.74	0.75	0.74
1982	0.72	0.73	0.63	0.75	0.88	0.61	0.72	0.74	0.71
1983	0.73	0.78	0.67	0.75	0.87	0.71	0.73	0.73	0.72
1984	0.71	0.78	0.68	0.74	0.87	0.71	0.71	0.77	0.73
1985	0.73	0.78	0.71	0.73	0.87	0.71	0.72	0.83	0.75
1986	0.77	0.77	0.76	0.73	0.89	0.77	0.72	0.81	0.75
1987	0.79	0.74	0.75	0.75	0.89	0.78	0.71	0.75	0.74
1988	0.82	0.75	0.77	0.73	0.91	0.79	0.70	0.74	0.73
1989	0.82	0.76	0.76	0.72	0.90	0.78	0.69	0.73	0.73
1990	0.84	0.74	0.75	0.73	0.90	0.71	0.70	0.74	0.72
1991	0.84	0.72	0.69	0.75	0.90	0.71	0.68	0.71	0.71
1992	0.89	0.74	0.66	0.75	0.88	0.71	0.67	0.65	0.68
1993	0.87	0.75	0.67	0.75	0.89	0.73	0.65	0.69	0.70
1994	0.87	0.79	0.67	0.76	0.89	0.78	0.67	0.69	0.71
1995	0.86	0.80	0.65	0.79	0.90	0.77	0.65	0.68	0.71
					Average				
1961-95	0.82	0.77	0.73	0.78	0.89	0.78	0.79	0.80	0.77
1961-73	0.86	0.78	0.78	0.83	0.91	0.85	0.89	0.87	0.82
1973-95	0.80	0.76	0.71	0.76	0.89	0.74	0.74	0.76	0.74
					Standard Deviation				
1961-95	0.07	0.05	0.06	0.04	0.02	0.08	0.09	0.07	0.05
1961-73	0.09	0.06	0.05	0.04	0.03	0.07	0.04	0.04	0.03
1973-95	0.05	0.05	0.04	0.02	0.01	0.05	0.06	0.06	0.03

Appendix Table 8.3A Markups of Canadian manufacturing industries

Year	Food and Beverage	Tobacco	Textiles	Clothing	Wood and Lumber	Furnitures	Pulp and Paper	Printing	Chemical Products	Refineries
1961	1.18	1.15	1.17	1.28	1.39	1.13	1.40	1.06	1.13	1.13
1962	1.19	1.18	1.17	1.27	1.44	1.14	1.40	1.06	1.21	1.15
1963	1.20	1.21	1.17	1.27	1.45	1.14	1.41	1.08	1.30	1.17
1964	1.21	1.22	1.17	1.27	1.40	1.15	1.42	1.10	1.32	1.18
1965	1.20	1.23	1.19	1.28	1.42	1.17	1.44	1.12	1.35	1.19
1966	1.20	1.28	1.21	1.29	1.40	1.18	1.45	1.14	1.46	1.21
1967	1.21	1.33	1.22	1.29	1.43	1.18	1.44	1.15	1.59	1.22
1968	1.23	1.37	1.24	1.30	1.45	1.19	1.46	1.17	1.69	1.23
1969	1.23	1.41	1.25	1.31	1.45	1.20	1.47	1.18	1.77	1.25
1970	1.25	1.42	1.26	1.32	1.49	1.21	1.46	1.15	1.79	1.27
1971	1.25	1.43	1.28	1.31	1.49	1.22	1.47	1.16	1.80	1.28
1972	1.24	1.43	1.28	1.31	1.52	1.22	1.49	1.18	1.81	1.30
1973	1.18	1.42	1.29	1.30	1.50	1.20	1.50	1.20	1.83	1.31
1974	1.18	1.41	1.26	1.29	1.42	1.20	1.48	1.16	1.79	1.22
1975	1.20	1.40	1.26	1.30	1.40	1.20	1.45	1.11	1.69	1.19
1976	1.23	1.41	1.26	1.30	1.38	1.20	1.46	1.13	1.75	1.19
1977	1.24	1.42	1.27	1.30	1.40	1.21	1.46	1.17	1.81	1.19
1978	1.23	1.46	1.28	1.30	1.38	1.21	1.47	1.20	1.91	1.22
1979	1.22	1.46	1.29	1.29	1.34	1.22	1.47	1.20	1.93	1.19
1980	1.23	1.43	1.25	1.28	1.31	1.21	1.44	1.21	1.86	1.16
1981	1.25	1.43	1.24	1.26	1.29	1.20	1.43	1.21	1.86	1.15
1982	1.27	1.38	1.21	1.26	1.25	1.18	1.41	1.22	1.71	1.14
1983	1.27	1.39	1.24	1.26	1.28	1.20	1.42	1.24	1.70	1.14
1984	1.26	1.35	1.24	1.27	1.30	1.20	1.43	1.28	1.61	1.17
1985	1.27	1.36	1.24	1.27	1.33	1.21	1.43	1.30	1.62	1.18
1986	1.29	1.36	1.26	1.27	1.37	1.21	1.43	1.30	1.57	1.22
1987	1.36	1.41	1.29	1.28	1.44	1.22	1.45	1.31	1.63	1.22
1988	1.37	1.41	1.29	1.28	1.48	1.24	1.47	1.32	1.62	1.24
1989	1.35	1.41	1.28	1.28	1.53	1.24	1.47	1.31	1.65	1.23
1990	1.35	1.38	1.28	1.27	1.54	1.23	1.44	1.31	1.57	1.21
1991	1.34	1.31	1.27	1.27	1.56	1.23	1.43	1.31	1.37	1.21
1992	1.32	1.29	1.26	1.26	1.58	1.22	1.40	1.29	1.34	1.20
1993	1.35	1.32	1.26	1.26	1.69	1.22	1.42	1.29	1.39	1.20
1994	1.36	1.35	1.26	1.26	1.70	1.22	1.42	1.29	1.48	1.21
1995	1.38	1.37	1.27	1.27	1.66	1.23	1.44	1.30	1.50	1.21
					Average					
1961-95	1.26	1.36	1.25	1.28	1.44	1.20	1.44	1.21	1.61	1.21
1961-73	1.21	1.31	1.22	1.29	1.45	1.18	1.45	1.13	1.54	1.22
1973-95	1.28	1.39	1.26	1.28	1.44	1.21	1.45	1.25	1.66	1.20
					Standard Deviation					
1961-95	0.06	0.08	0.04	0.02	0.11	0.03	0.03	0.08	0.21	0.04
1961-73	0.02	0.11	0.05	0.02	0.04	0.03	0.03	0.05	0.26	0.06
1973-95	0.07	0.04	0.02	0.02	0.13	0.01	0.03	0.07	0.17	0.04

Appendix Table 8.3A Markups of Canadian manufacturing industries (continued)

Year	Rubber and Plastic Products	Leather Products	Non-Metallic Mineral Products	Primary Metals	Fabricated Metal Products	Commercial and Industrial Machinery	Electrical and Electronic Products	Trans-portation Equipment	Manu-facturing
1961	1.08	1.24	1.11	1.22	1.12	1.17	1.10	1.08	1.18
1962	1.10	1.23	1.12	1.22	1.13	1.18	1.12	1.11	1.20
1963	1.10	1.23	1.12	1.24	1.13	1.19	1.12	1.12	1.21
1964	1.11	1.24	1.14	1.24	1.14	1.21	1.12	1.12	1.22
1965	1.13	1.23	1.15	1.26	1.15	1.24	1.14	1.13	1.22
1966	1.15	1.24	1.16	1.28	1.17	1.27	1.16	1.16	1.24
1967	1.16	1.24	1.17	1.26	1.18	1.27	1.16	1.16	1.26
1968	1.18	1.24	1.18	1.28	1.19	1.28	1.19	1.18	1.28
1969	1.20	1.24	1.19	1.28	1.19	1.30	1.20	1.19	1.29
1970	1.22	1.25	1.19	1.31	1.20	1.30	1.19	1.14	1.29
1971	1.24	1.26	1.20	1.30	1.21	1.30	1.18	1.16	1.30
1972	1.23	1.25	1.22	1.33	1.22	1.34	1.20	1.18	1.31
1973	1.25	1.25	1.23	1.30	1.23	1.37	1.24	1.22	1.31
1974	1.22	1.23	1.21	1.28	1.21	1.34	1.21	1.17	1.28
1975	1.15	1.23	1.19	1.24	1.19	1.32	1.17	1.14	1.26
1976	1.17	1.23	1.19	1.24	1.19	1.34	1.19	1.17	1.28
1977	1.22	1.24	1.20	1.25	1.22	1.38	1.23	1.20	1.30
1978	1.24	1.25	1.21	1.27	1.21	1.43	1.25	1.22	1.32
1979	1.23	1.25	1.20	1.26	1.22	1.47	1.27	1.22	1.32
1980	1.19	1.24	1.18	1.22	1.23	1.47	1.27	1.16	1.31
1981	1.21	1.24	1.17	1.22	1.20	1.49	1.28	1.14	1.31
1982	1.19	1.24	1.15	1.16	1.14	1.41	1.26	1.11	1.27
1983	1.21	1.24	1.16	1.16	1.15	1.39	1.28	1.15	1.28
1984	1.27	1.24	1.17	1.17	1.14	1.48	1.34	1.20	1.28
1985	1.28	1.22	1.17	1.18	1.16	1.52	1.32	1.21	1.29
1986	1.30	1.22	1.17	1.19	1.16	1.53	1.33	1.22	1.30
1987	1.32	1.22	1.16	1.21	1.15	1.56	1.44	1.24	1.34
1988	1.37	1.21	1.17	1.21	1.13	1.61	1.48	1.25	1.35
1989	1.35	1.21	1.15	1.22	1.12	1.57	1.53	1.28	1.36
1990	1.33	1.19	1.15	1.21	1.08	1.53	1.54	1.28	1.35
1991	1.30	1.18	1.13	1.19	1.07	1.52	1.56	1.25	1.32
1992	1.26	1.18	1.12	1.15	1.07	1.47	1.58	1.23	1.30
1993	1.29	1.18	1.11	1.15	1.10	1.50	1.69	1.24	1.33
1994	1.32	1.19	1.11	1.14	1.11	1.56	1.70	1.26	1.36
1995	1.32	1.19	1.11	1.15	1.10	1.58	1.76	1.28	1.37
Average									
1961-95	1.23	1.23	1.16	1.23	1.16	1.40	1.31	1.19	1.29
1961-73	1.17	1.24	1.17	1.27	1.17	1.26	1.17	1.15	1.25
1973-95	1.26	1.22	1.17	1.21	1.16	1.47	1.39	1.21	1.31
Standard Deviation									
1961-95	0.08	0.02	0.03	0.05	0.05	0.13	0.18	0.05	0.05
1961-73	0.06	0.01	0.04	0.03	0.04	0.06	0.04	0.04	0.04
1973-95	0.06	0.02	0.03	0.05	0.05	0.08	0.18	0.05	0.03

Appendix Table 8.4A Parametric annual multifactor productivity growth rates of the Canadian manufacturing sector

Year	Food and Beverage	Tobacco	Textiles	Clothing	Wood and Lumber	Furnitures	Pulp and Paper	Printing	Chemical Products	Refineries
					Percentage					
1962	0.73	-0.65	3.47	2.06	1.89	0.58	0.01	2.16	1.91	4.77
1963	0.29	2.52	1.61	1.43	2.78	1.00	0.53	0.31	1.41	0.55
1964	0.23	1.74	0.16	-0.13	1.08	0.19	0.71	-0.20	2.01	1.65
1965	0.68	1.37	-0.89	0.91	-0.10	1.43	-0.04	0.01	0.82	1.18
1966	0.49	-1.40	-0.50	0.73	-0.20	0.43	-0.01	0.34	0.47	0.93
1967	0.16	-0.90	-0.10	-0.80	0.06	0.19	-0.90	0.13	-0.20	-1.70
1968	-0.25	-0.68	2.87	1.33	2.44	0.29	0.35	0.18	0.75	0.95
1969	0.19	1.19	2.10	0.18	1.39	0.99	1.05	0.66	1.55	-0.90
1970	1.25	1.41	-0.10	-0.09	0.22	-0.80	-0.10	-0.90	-0.90	0.28
1971	0.99	2.89	1.79	2.13	0.61	0.46	-0.20	0.28	1.68	0.92
1972	0.25	1.77	2.46	1.73	-0.04	1.83	1.10	2.83	1.45	-0.10
1973	0.33	1.33	0.61	1.97	-0.09	0.99	1.08	3.30	2.27	1.95
1974	-0.13	3.23	0.35	-0.80	-1.00	-1.92	1.24	0.03	-0.10	-1.40
1975	-0.95	1.60	0.76	-0.89	-1.10	-0.70	0.89	1.45	-0.99	-0.12
1976	0.19	-0.93	0.90	1.09	0.98	0.66	1.12	1.08	0.26	-0.02
1977	0.20	2.70	1.40	1.75	2.40	0.50	0.15	2.36	1.40	2.20
1978	-0.03	-2.10	1.70	-1.21	-0.90	1.63	1.40	1.70	1.63	-0.90
1979	0.02	0.75	1.94	-0.80	-0.70	-1.20	-0.40	-0.70	-0.20	-0.70
1980	-0.31	0.75	-0.08	2.71	2.63	-0.80	0.28	-0.02	-1.80	0.74
1981	-0.18	-0.20	0.88	0.58	0.56	1.50	-0.70	-0.10	2.99	1.36
1982	-0.06	0.39	-0.91	-0.13	-0.35	-1.12	-0.77	-1.40	-1.10	0.24
1983	-0.06	-1.29	1.10	1.40	1.08	0.80	0.80	0.86	0.89	0.69
1984	0.20	-1.17	0.21	1.90	1.17	1.01	1.01	0.99	0.97	0.14
1985	0.24	-2.20	0.64	2.50	1.14	1.14	0.47	0.15	1.01	0.45
1986	-0.14	-2.59	2.13	0.07	0.07	-0.01	0.28	0.01	2.62	0.04
1987	0.16	7.77	0.41	4.54	4.40	-2.20	0.59	-0.70	2.12	1.50
1988	-0.04	3.72	-0.96	-0.80	-0.89	-1.10	-0.80	-1.00	1.89	0.44
1989	-0.38	2.33	0.32	-1.00	-0.78	-0.10	-1.40	-0.80	2.89	1.19
1990	0.34	-4.30	-0.80	-1.20	-1.20	1.57	-1.70	-0.40	-0.80	0.39
1991	0.15	0.71	-0.60	-0.90	-1.00	-1.80	-0.80	-4.60	-2.70	-0.10
1992	0.08	-0.80	0.96	1.40	0.80	1.10	0.80	-1.20	0.20	0.26
1993	-0.05	-5.06	1.34	0.06	0.06	1.24	1.15	-2.20	2.96	-0.70
1994	0.39	0.99	1.17	-1.57	-1.52	1.26	1.31	-0.20	1.11	1.09
1995	0.99	0.76	1.83	-0.90	-0.10	1.50	1.90	0.14	1.12	2.20
					Average					
1961-95	0.17	0.46	0.83	0.57	0.46	0.31	0.31	0.13	0.87	0.57
1961-73	0.44	0.88	1.12	0.95	0.84	0.63	0.30	0.76	1.10	0.87
1973-95	0.04	0.28	0.67	0.42	0.25	0.17	0.34	-0.05	0.81	0.48
					Standard Deviation					
1961-95	0.42	2.41	1.13	1.43	1.36	1.11	0.86	1.46	1.38	1.21
1961-73	3.61	0.41	1.42	1.44	0.98	1.06	0.68	0.62	1.29	0.95
1973-95	6.78	0.36	2.76	0.90	1.61	1.45	1.26	0.98	1.60	1.57

Appendix Table 8.4A Parametric annual multifactor productivity growth rates of the Canadian manufacturing sector (continued)

Year	Rubber and Plastic Products	Leather Products	Non-Metallic Mineral Products	Primary Metals	Fabricated Metal Products	Commercial and Industrial Machinery	Electrical and Electronic Products	Trans-portation Equipment	Manu-facturing
					Percentage				
1962	4.51	2.51	4.48	2.35	1.95	4.46	3.54	1.73	1.87
1963	1.14	1.08	0.95	1.58	0.83	0.35	0.64	1.61	1.00
1964	1.28	2.28	2.42	1.32	1.66	3.84	2.05	0.29	1.09
1965	0.64	-0.10	1.05	1.00	1.28	0.78	1.29	1.46	0.87
1966	0.92	-0.10	0.26	-0.10	-0.11	1.74	-0.25	-0.44	0.13
1967	-0.20	-0.20	-1.20	-0.80	-0.23	-1.10	-0.16	1.76	0.01
1968	2.07	0.33	2.05	1.86	0.31	-0.05	1.26	0.88	0.78
1969	0.82	0.68	1.26	0.96	0.30	2.32	1.37	1.84	1.07
1970	-0.80	0.54	-0.80	-0.10	-0.44	-0.10	-0.22	-0.18	0.07
1971	0.45	1.04	4.34	-0.90	0.73	-1.20	1.39	2.23	0.97
1972	0.87	-0.70	4.06	-0.11	0.67	1.01	2.56	1.33	0.97
1973	3.19	0.38	1.46	0.69	1.11	2.49	2.39	1.18	1.10
1974	-2.20	2.63	-0.10	-0.40	1.23	3.29	-0.18	1.25	0.37
1975	-1.50	1.30	-0.80	-1.12	-0.13	-0.79	-0.87	0.72	-0.43
1976	1.99	1.64	0.80	-0.12	1.20	1.20	2.98	1.10	0.79
1977	2.16	0.50	-0.90	2.20	0.90	1.08	3.10	0.20	0.98
1978	1.63	2.85	0.80	1.56	0.20	1.00	-0.96	0.50	0.51
1979	1.90	-1.10	0.14	-1.20	-0.11	4.21	5.54	-0.14	0.25
1980	-1.80	0.68	-2.10	0.04	1.21	0.15	2.40	-1.40	-0.08
1981	1.43	1.21	-0.80	-1.80	0.47	-0.75	0.44	1.33	0.31
1982	-1.20	-0.50	-1.10	-1.12	-0.99	-2.20	-1.25	0.11	-0.62
1983	1.04	0.79	1.01	0.74	0.11	-2.58	-0.18	1.25	0.49
1984	1.85	1.25	0.85	1.35	1.72	0.16	0.87	1.09	0.90
1985	1.99	0.14	1.16	1.78	1.44	1.15	1.11	1.12	0.98
1986	-0.91	0.52	1.74	0.77	1.78	2.12	0.47	-0.16	0.61
1987	1.29	0.55	3.05	1.76	0.36	0.74	0.92	-0.23	0.90
1988	-2.70	-0.10	-0.10	-0.40	-0.05	3.12	-0.14	3.19	0.83
1989	-1.20	0.91	-1.01	1.47	0.33	0.09	3.25	1.05	0.74
1990	0.23	-0.90	-1.50	-0.01	0.39	0.43	-0.55	-0.17	-0.26
1991	-1.40	-1.10	-1.50	0.26	-0.80	-1.12	-1.23	-0.18	-0.70
1992	1.08	0.25	0.78	0.80	0.14	-0.15	0.78	0.72	0.46
1993	2.21	-0.10	1.20	1.20	0.28	1.10	0.35	1.16	0.86
1994	1.15	0.87	1.90	-0.10	1.45	2.21	1.20	2.21	1.08
1995	1.04	0.95	0.85	1.80	1.14	1.08	1.17	0.98	1.10
					Average				
1961-95	0.68	0.62	0.73	0.51	0.60	0.88	1.03	0.86	0.59
1961-73	1.24	0.64	1.69	0.65	0.67	1.21	1.32	1.14	0.83
1973-95	0.49	0.59	0.25	0.44	0.58	0.78	0.94	0.73	0.49
					Standard Deviation				
1961-95	1.60	1.00	1.67	1.10	0.75	1.71	1.54	0.93	0.81
1961-73	1.60	1.44	0.97	1.88	1.05	0.75	1.81	1.19	1.50
1973-95	0.96	1.70	1.01	1.30	1.12	0.76	1.68	1.69	2.12

Appendix 1 – The Statistics Canada Productivity Program: Concepts and Methods

Tarek M. Harchaoui, Mustapha Kaci and Jean-Pierre Maynard

A.1 Introduction

This appendix describes the concepts and methods underlying Statistics Canada's indices of productivity growth. Its primary objective is to provide an accessible guide to the various productivity measures produced by Statistics Canada within a coherent framework that strikes a balance between theoretically desirable characteristics of productivity measures and the reality of data availability. A second objective is to indicate how Statistics Canada's productivity measures compare with those produced by the U.S. Bureau of Labor Statistics and the Organisation for Economic Co-operation and Development (OECD) for cross-country comparison purposes. Finally, the appendix provides comments on some of the conceptual and empirical obstacles to further improvements in the measure.

The publication of productivity measures has long been an important activity of Statistics Canada. This measurement program has evolved over the years, stimulated by changes in data availability, by new developments in the economics literature, and also by the needs of data users. Following the development of the Canadian System of National Accounts (CSNA) after the Second World War, Statistics Canada introduced labour productivity measures for the aggregate business sector and its major constituent subsectors.[1] More recently, the agency has developed measures of multifactor productivity. These measures, which consider the productivity of a bundle of inputs (labour, capital, and purchased goods and services[2]), are often used as 'red flags' to measure the extent to which economic performance differs across industries, across countries and over time.

Statistics Canada's productivity program has the following characteristics often shared by those of other statistical offices. First, it focuses exclusively on comparisons based on productivity growth measures as opposed to productivity levels. At present, rates of change are preferred because they avoid methodological and data problems associated with productivity level comparisons. Second, the program produces various kinds of productivity measures of the business sector and its major constituents (subsectors and industries).

[1] The definition of business sector used for productivity measures excludes all non-commercial activities as well as the rental value of owner-occupied dwellings. Corresponding exclusions are also made to the inputs. Business gross domestic product (GDP), as defined by the productivity program, represents 71% of the economy GDP in 1992. The business sector is split into the following major subsectors: goods-producing, services and manufacturing. The goods-producing subsector consists of agriculture, fishing, forestry, mining, manufacturing, construction and public utilities. Services comprise transportation and storage, communications, wholesale and retail trade, finance, insurance and real estate, and the group of community, business and personal services.

[2] Purchased goods and services are known as intermediate inputs in the CSNA.

A.2 Theory and concepts

A.2.1 Productivity measures

Productivity growth is commonly defined as the difference between the percentage change of a measure of output and the percentage change of a measure of inputs used. It is meant to capture the growth in productive efficiency arising from technical progress. Productivity growth is the growth of output not accounted for by the growth of an input or inputs.

There are various productivity growth measures. The choice between them depends on the purpose of productivity measurement and, in many instances, on data availability. In general, productivity measures can be grouped into two broad categories:

1. The first is single-factor productivity where growth in output is compared with growth of input. The most commonly used single-factor productivity measure is labour productivity (LP) growth , measured as:

$$\Delta\, LP = \Delta\, Q - \Delta\, L\,, \tag{1}$$

   where Δ refers to discrete changes in percentage with respect to time; Q and L represent, respectively, output and labour.

   Although labour productivity growth is an important measure, it is not the only way to measure gains in productive efficiency. Economic performance as measured by labour productivity must be interpreted carefully, since these estimates reflect changes in the other inputs (e.g., capital) in addition to growth in productive efficiency. The production of output requires the combination of all inputs in a technologically feasible manner. Hence, productivity is also measured in a way that compares output with the combined use of all resources, not just labour. For example, the construction of a complex plant with substantial expenditures on capital equipment but only minimal operating expenditures for labour may generate an apparently impressive labour productivity index, but the total amortized capital, plus labour cost may be much higher than those of a less complex but slightly more labour-intensive plant that would be more efficient while yielding a smaller labour productivity index. For these reasons, caution is in order in the interpretation of either rapid gains or 'disturbing slowdowns' in labour productivity growth. This sentiment is shared, incidentally, by both labour economists and productivity analysts (Griliches 1980; Rees 1980).

2. Users are therefore encouraged to consider a second way of measuring productivity growth, one that complements labour productivity growth. This second measure is known as multifactor productivity growth (MFP), the difference in the growth in output (Q) minus the growth in a bundle of inputs (I):

$$\Delta\, MFP = \Delta\, Q - \Delta\, I\,. \tag{2}$$

   Multifactor productivity growth is often characterized as arising from an outward shift in the production function resulting from technical progress. The concept of multifactor productivity, developed by Solow (1958), depends, for the sake of simplicity, upon the assumptions of constant returns to scale, perfect adjustments to the inputs and competitive markets. It measures technical progress as a residual; that is, the growth of the output is not due to the growth of the inputs. But Solow

Table A1.1 Most commonly used concepts of productivity

Concept of inputs	Concept of output	
	Gross output	Value added
Labour	–	Labour productivity
Capital	–	–
Combined capital and labour	–	Multifactor productivity
Combined capital, labour, energy, materials and services	Multifactor productivity	–

also acknowledged that multifactor productivity so measured reflects many other influences, because it is calculated as a residual.

Other research has made contributions facilitating the implementation of the multifactor productivity framework by statistical agencies. Domar (1961) demonstrated how a system of industry and aggregate production functions could be used to produce a set of industry productivity measures that are consistent with the aggregate measures for the economy as a whole. Jorgenson and Griliches (1967) showed how detailed data could be used to construct a capital aggregate without making strong assumptions about the relative marginal products of dissimilar assets. Also, it was recognized that fixed-based formulas could introduce bias into the aggregating process. Diewert (1976) showed how production functions could be used to provide a basis for determining which index number formulas were least restrictive. He developed a number of arguments detailing the attractive properties of superlative indices.

Measures of productivity differ partly because of the comprehensiveness of inputs covered. They also differ in terms of the measure of output used. There are two major distinctions—whether output is measured by value added or by gross final output. Table A1.1 lists a variety of single-factor and multifactor productivity concepts that are generally used for different analytical purposes. In the first case, the bundle of inputs consists of labour and capital. In the second case, it consists of labour, capital, energy, materials, and services.

A.2.2 Output and inputs

A.2.2.1 Output current prices

The information needed for the measurement of production activity is drawn from the income statement of individual businesses. In the income statement, revenues come mainly from sales; costs of goods and services sold include mainly purchased goods and services and labour compensation (wages and salaries and supplementary labour income).

Rearranged and modified, the income statement for the business unit provides the production account that constitutes the starting point for deriving the input-output accounts of an industry. The production account, derived from the income statement through some suitable modifications,[3] records the production attributable to the business unit in

[3] These modifications are necessary because sales (shown in the income statement) are not equal to the value of production. Sales are not equivalent to gross output because the business unit may either make sales from inventories of finished goods produced in previous periods or place current production in inventories. Thus, gross output is obtained as the sum of sales and the value of changes in inventories.

Table A1.2 Production account of producing units A1 and A2

Uses		Resources		
Producing unit A1				
Labour compensation	380	Gross output		+1,000
Surplus or compensation of capital	+120			
		Producing unit A1	120	
		Producing unit A2	+300	
		Industry B	+ 80	
		Purchased goods and services		-500
Charges against output	500	Value added		500
Producing unit A2				
Labour compensation	150	Gross output		300
Surplus or compensation of capital	+ 50			
		Producing unit A1	50	
		Producing unit A2	+ 0	
		Industry B	+50	
		Purchased goods and services		-100
Charges against output	200	Value added		200

Table A1.3 Production account of industry A (consolidation of producing units A1 and A2)

Uses		Resources		
Labour compensation	530	Gross output		1,300
Surplus or compensation of capital	+170	Intra-industry flows of goods and services	-470	
		Gross output net of intra-industry transactions		830
		Purchased goods and services (industry B)	-130	
Charges against output	700	Value added		700

terms of both goods and services produced and the income payments and other costs arising in production.

For the sake of an illustration, consider a business sector with two industries A and B, where A comprises two producing units A1 and A2. Table A1.2 displays the production accounts of these two units. For example, to produce $1,000 of output, the unit A1 consumes a portion of its own output ($120), a portion of the output produced by industry B ($80) and the whole output of the unit A2 ($300); it also hires employees who are paid $380. Once the employees and the purchased goods and services have been paid, the unit A1 is left with a residual of $120 to compensate the owners of capital.

The production account gives rise to two concepts of output. The first is value added, which is the sum of compensation of the primary inputs—labour and capital; this is also known as gross domestic product (GDP). The second is gross output, which is the sum of value added and the value of purchased goods and services. Value added constitutes an unduplicated measure of output. In addition, the sum of value added across all producing units is invariant to the degree of vertical integration between those units. In that sense, value added is perfectly additive. Table A1.3, which consolidates the information of the production units A1 and A2, shows that value added remains the same. By

contrast, gross output suffers from double counting as the value of purchased goods and services by a unit has already been counted as output of another unit and the consolidation of producing units will change the measure of gross output.

Different measures of output are adopted by productivity practioners, depending on how they treat those transactions that occur within industry A (the consolidation of units A1 and A2), i.e., intra-industry deliveries of intermediate inputs. If the producing units A1 and A2 were integrated together into a single consolidated 'establishment' covering the whole industry A, then intra-industry purchases are netted out and gross output is then defined net of intra-industry transactions.[4] The production accounts of producing units A1 and A2 indicate that the inclusion of intra-industry flows of purchased goods and services adds identically to both the input and output side of industry A's production account, as the value of gross output and the value of purchased goods and services change with the exclusion of intra-industry transactions (Table A1.3).

The process of vertical integration may be pushed one step further to cover not only intra-industry sales but also inter-industry sales. The establishments of an industry may be integrated with their upstream suppliers, which may themselves be integrated upstream with their own suppliers. The associated concept of output in this case is called inter-industry output as it takes into account the inter-industry transactions (Rymes 1972; Wolfe 1991; Durand 1996). Under full integration, the output of industries becomes a function of the direct use of the industries' own primary inputs and the indirect use of the primary inputs of all upstream suppliers.

Constant prices

Productivity measures require estimates of real output produced and real inputs used in the production process. This is done by estimating the value of output and inputs in constant prices. The notion of constant prices is not one that can be defined in terms of physical units of output and inputs. There is no meaningful way to tally up, on a common physical unit of measurement, the diverse range of goods and services found in the economy. Rather, the aggregation is performed in monetary terms as the value, at fixed prices, of the goods and services included in the output and inputs.

The technique employed for deriving constant price series of value added is known as the 'double deflation' method. This involves deflating the gross output and the intermediate inputs separately and subtracting one from the other. This derivation of industry real output circumvents the problem of deflating the compensation of primary inputs, an alternative that could be used.

A.2.2.2 Inputs

Labour input

Over time the composition of the labour force has changed significantly in Canada, as in many other developed countries: more jobs are non-standard (part-time, temporary and self-employed); the distribution of hours worked has become more polarized (the number of persons working both short and long hours has steadily increased over the last two decades). If labour is measured in terms of number of employees, no consideration is given to the fact that some employees work a standard workweek and others do not. Measuring labour input as the number of hours worked deals with this aspect of heterogeneous labour input.

[4] This concept of output net of intra-industry transactions is also known as sector output (Gollop 1979).

Labour also varies considerably in terms of quality. For example, education has been increasing. Measuring labour input may be done either via simple aggregates or by aggregating different types of labour using different weights, based on their relative wage rate. The former ignores differences in quality. The latter adjusts for quality differentials by assuming that they are reflected in relative wage rates.

Capital input

Capital input shares some of the same characteristics as labour input. Capital goods purchased or rented by a firm also constitute repositories of capital services, much like employees hired for a certain period of time who can be seen as carriers of human capital and, therefore, as repositories of labour services. There is, however, an important difference between labour and capital: except for rented capital, no market transaction is actually recorded when capital provides services to its user. Therefore, unlike labour, no explicit price and quantity of the service rendered can be observed for capital. An implicit measure of the price of capital services, derived from the ratio of capital compensation to the stock of capital, captures the internal rate of return used in the cost of capital formula. This measure, which varies only across industries, is used to construct capital services at the level of the business sector or its subsectors (such as manufacturing and services).

As with labour, measures of capital growth can be made as simple aggregates across capital types (machinery versus buildings) or by weighting the different asset classes by weights that reflect differences in the capital services yielded by a dollar of assets in each category.

Intermediate inputs

Estimates of intermediate inputs such as energy, materials and services in current and constant prices are required for the construction of gross output, value added and, ultimately, multifactor productivity series. The weighted sum of the growth rates of intermediate inputs in constant prices enters into the calculation of a) value added in constant prices (double deflation technique) and b) multifactor productivity estimates based on gross output. The weights of intermediate inputs are defined as the ratio of the value of each intermediate input to gross output in current prices.

A.3 Measurement framework

A.3.1 Productivity measures at Statistics Canada

Statistics Canada publishes several sets of productivity measures for the Canadian business sector and its major constituent subsectors (goods producing, services and the manufacturing subsectors) and industries. Each set of measures involves a comparison of the growth in output and input measures, but each relies on a different methodology. The concept of business sector excludes general government, private households, nonprofit organizations and the CSNA imputation of the rental value of owner-occupied dwellings. The business sector thereby excludes activities where it is difficult to draw inferences on productivity from the CSNA output measures. Such inferences would be questionable mainly because the CSNA output measures in these areas are based largely on incomes of inputs in constant prices, where productivity growth must therefore be zero by construction.

The traditional measure of labour productivity—output per hour—constitutes the first measure of productivity introduced by Statistics Canada in the early 1960s. Output, measured net of price change, is compared to labour input, measured as hours at work in the corresponding sector or industry.

The second set of measures covers multifactor productivity. In these measures, output is again measured net of price changes, but the input measure is an aggregate of hours worked and capital service flows. Multifactor productivity estimates have been developed in recognition of the role capital growth plays in output growth.

Both labour and multifactor productivity estimates have been published annually since 1961 and are updated on a yearly basis following the annual revisions made by the CSNA. Labour productivity estimates are *published* for 109 industries, compared with 101 for multifactor productivity as capital stock estimates are not always available at the same level of industry detail as the input-output tables.[5]

Statistics Canada's productivity estimates are based on a bottom-up approach to productivity measurement. Productivity indices are estimated with the most detailed data available by industry and by goods and services. Productivity indices are *computed* for 147 industries in the case of labour productivity and 122 industries in the case of multifactor productivity and then aggregated by steps up to the total business sector. This approach, which takes advantage of homogenous information available at a fine level of detail, proves to be superior to the aggregated approach as it significantly improves the quality of the measured aggregate productivity indices.[6]

A.3.1.1 Labour productivity and related measures

Labour productivity, calculated as the difference in the growth rate between GDP at basic price and the number of hours are available at the L-level of input-output tables (147 industries of the business sector). Appendix 2 provides a list of various levels of aggregation used by the productivity program. Since input-output tables are usually three years behind the reference year,[7] more current estimates are produced by using projections of GDP for a high level of aggregation—16 industries (the S-Level of input-output tables). These projections are based on a regression model developed by Mirotchie (1996), where the Fisher GDP is regressed on the Laspeyres GDP and a set of three time dummy variables capturing the lag between the reference year and the last year for which input-output tables are available.

Parallel to the labour productivity indices, Statistics Canada's productivity program also produces other performance indicators, such as indices of compensation per hour and unit labour cost. Indices of compensation per hour measure the hourly cost to employers of wages and salaries, as well as supplemental payments, which include employers' contributions to employment insurance taxes and payments for private health insurance and pension plans.

Unit labour costs measure the cost of labour input required to produce one unit of output. The index of unit labour costs is derived by dividing the compensation index in current dollars by the output index.

[5] Input-output tables, which constitute the major source of data used in the productivity estimates, provide information on input and output for 167 industries. See section A.3.2, "Estimation procedures and data sources."

[6] As stated by Jorgenson (1990), the assumptions that are necessary to admit the existence of an aggregate production function are rather heroic. Its existence requires that such a function be the same for all industries and that producers face identical prices. He showed that estimates of productivity made at the aggregate level under these assumptions may significantly depart from those obtained by aggregating detailed industry productivity estimates, based on less stringent assumptions.

[7] The reference year is the most current year for which annual series can be produced.

A.3.1.2 Multifactor productivity

The productivity program produces four categories of multifactor productivity indices, each of which responds to a different analytical need:

1. At the level of the business sector or its sub-sectors, multifactor productivity indices are measured as the value-added output per combined unit of labour and capital input.

2. At the industry level, comparisons of gross output (i.e., value-added *plus* intermediate inputs) with a broader set of inputs constitute a second category of multifactor productivity indices, known as the **industry** indices. They measure the growth in the gross output of an industry not accounted for by the growth in all of its inputs (capital, labour and the intermediate inputs, which are the materials and services purchased from other industries). These indices do not take into account the productivity gains that take place in the (upstream) industries that produce these intermediate inputs.

3. **Intra-industry** multifactor productivity indices, in which intra-industry sales are netted out from gross output, constitute a variant of the industry indices. In this instance, multifactor productivity growth is computed as if all establishments in a particular industry were integrated together into a single consolidated establishment covering the whole industry. That establishment sells all its output outside the industry and purchases all its intermediate inputs outside the industry. Accordingly, intra-industry purchases are excluded in the intra-industry integrated inputs.

4. None of the above multifactor productivity indices of a particular industry accounts for the productivity gains made by its upstream suppliers. By contrast, the **inter-industry** multifactor productivity indices do just that. They also include the productivity gains realized in the upstream industries supplying intermediate inputs.[8]

The inter-industry index measures the growth in the output of an industry not accounted for by the growth in all its primary inputs as well as by the growth in the primary inputs used in the production of its intermediate inputs by its direct and indirect industry suppliers. The inter-industry productivity indices take into account all the primary inputs that have been used in the business sector as a whole to produce a given bundle of goods and services. They may be seen as productivity indices attached to commodity bundles rather than to industries (Durand 1994).

These four measures clearly show that the concept of multifactor productivity can be defined for various industrial aggregation levels and also for various levels of vertical integration (measures 3 and 4) (see Figures 1 to 5). This variety of multifactor productivity indices are produced to satisfy various analytical needs expressed by data users. For example, in an effort to assess the performance of an economy as a whole in the production of some bundle of goods, it would be inappropriate to consider the declining industries with low productivity gains without also looking at the performance of the industries supplying them with goods and services. The ability of sellers of automobiles to pass on price savings due to productivity gains arises from productivity improvement not just in the auto assembly sector but also in auto parts, plastic, rubber, and a host of other upstream industries.

[8] The concept and the empirical estimates were first introduced by Cas and Rymes (1991). However, contrary to Cas and Rymes, the inter-industry multifactor productivity estimates produced by Statistics Canada include the capital stock in the primary inputs rather than in intermediate inputs.

Figure 1. Business Sector

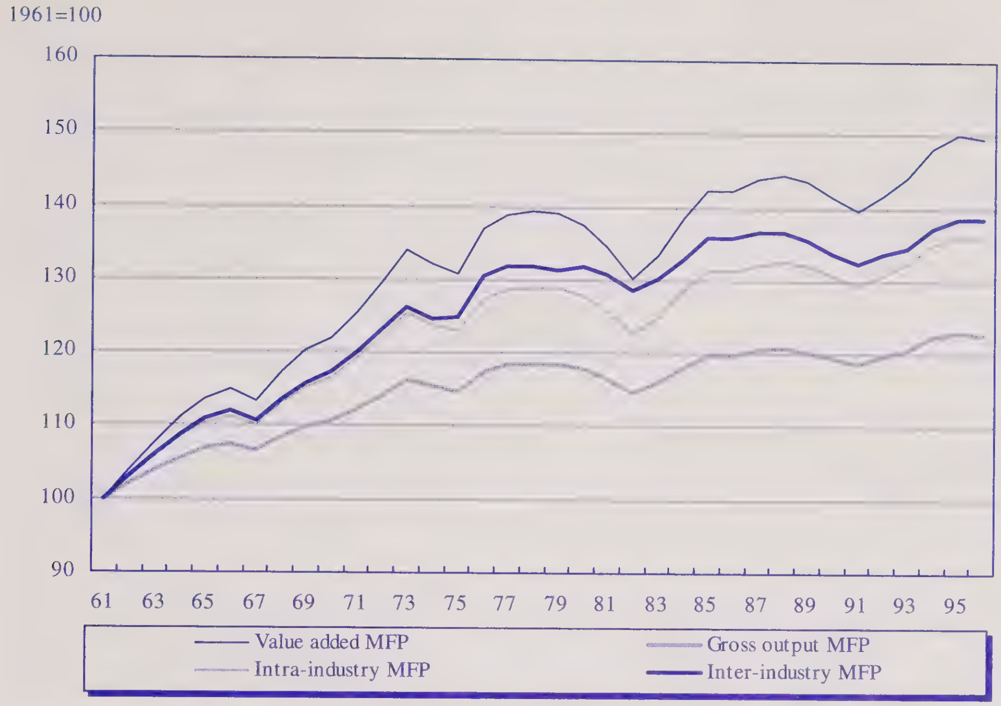


Figure 2. Business Sector excluding Agriculture

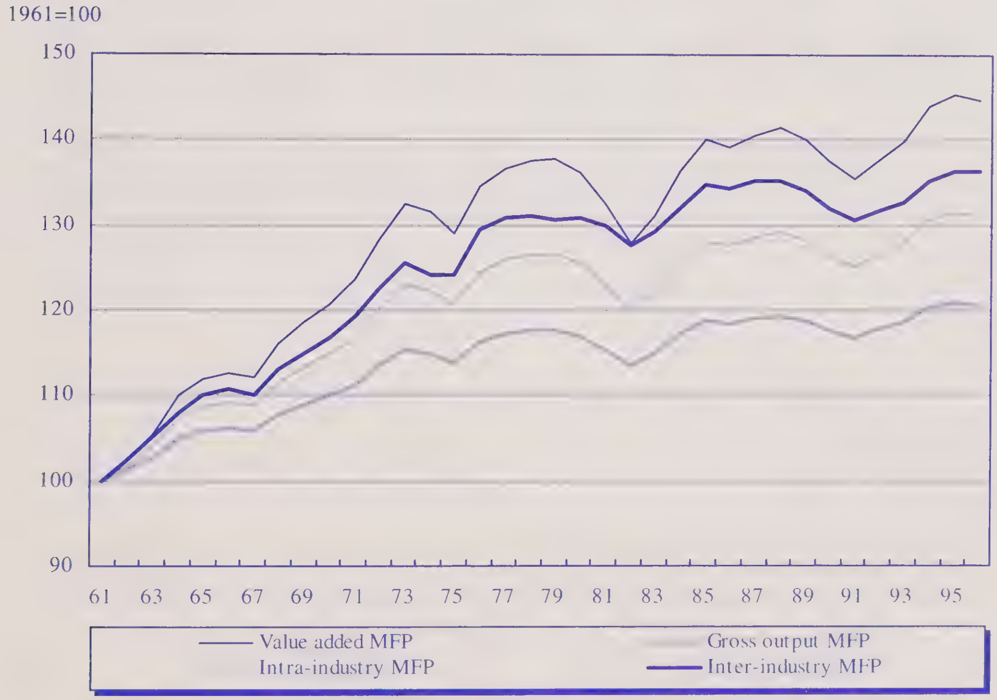


Figure 3. Business Sector – Goods Producing Industries

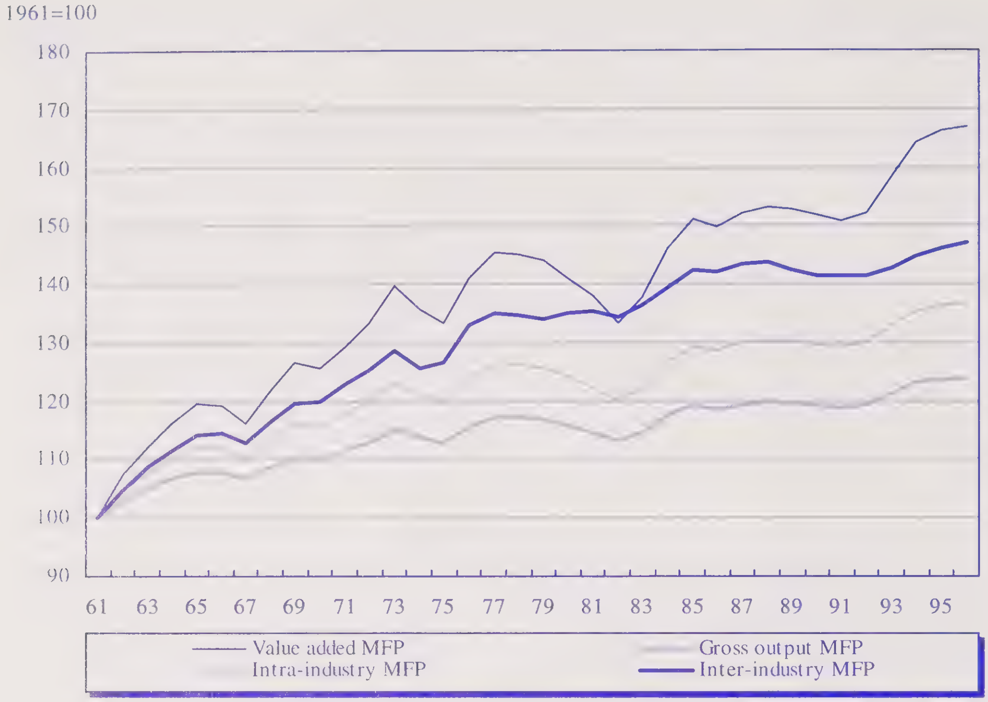


Figure 4. Business Sector – Services Producing Industries

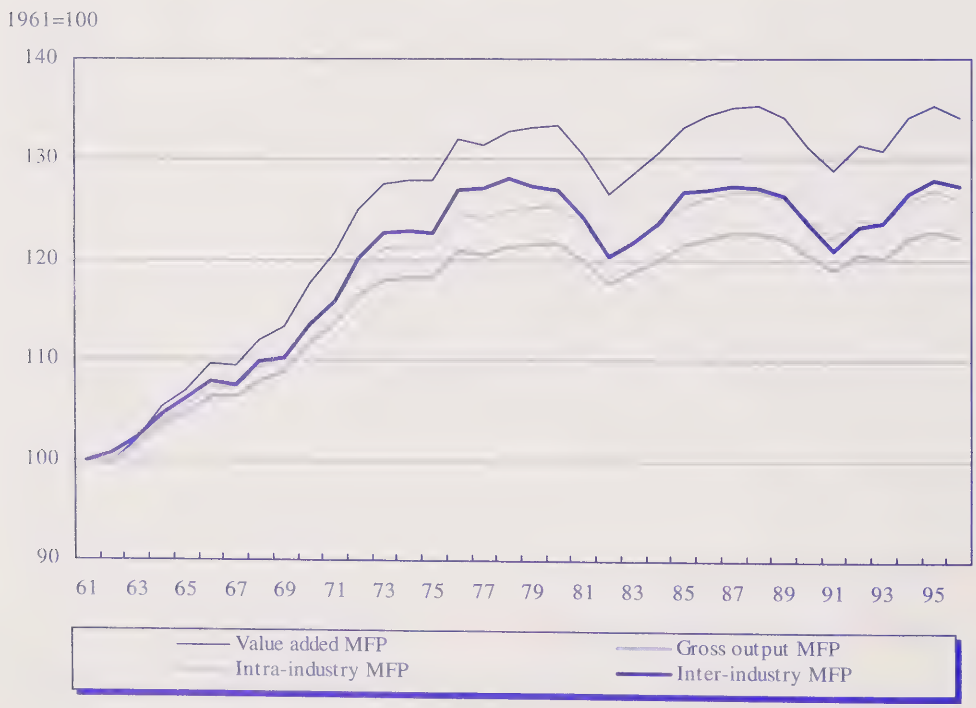
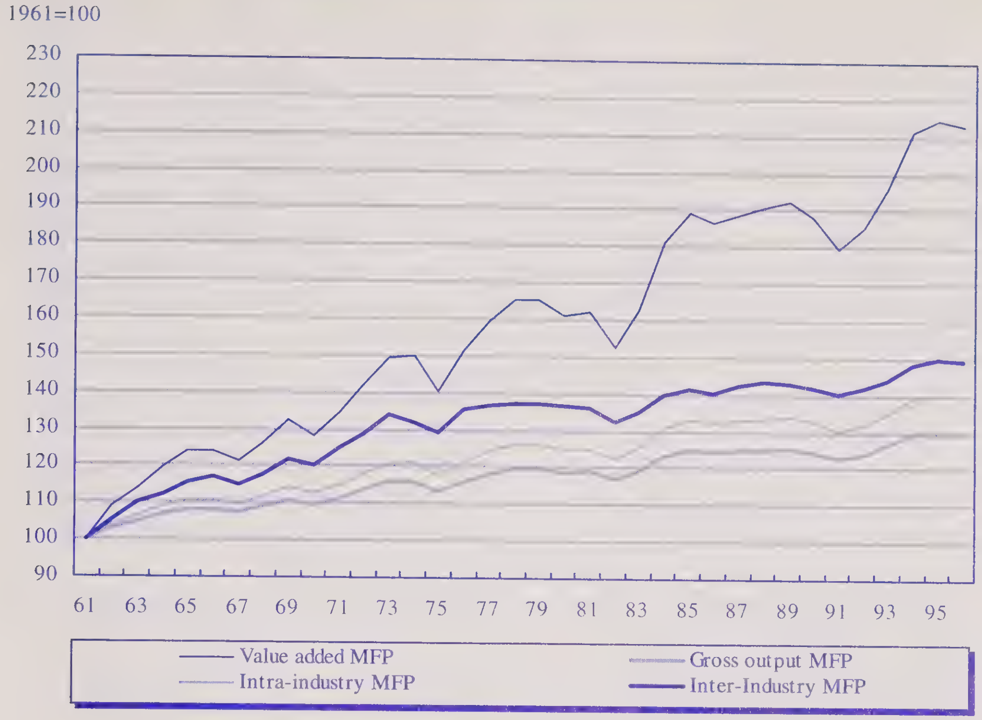


Figure 5. Manufacturing Industries



It is important to note that there are significant differences in the empirical estimates of different multifactor productivity measures (see Figures 1 to 5). The higher in the value added chain the estimate goes, the larger will be the productivity estimate. Comparisons that are made across countries that do not use the same level in the chain will contain inherent biases.

The relationship between the various multifactor productivity indices that are produced can be derived in a straightforward fashion.

The productivity growth estimates calculated using value added of an industry is just equal to the productivity growth estimates using gross output multiplied by an inflation factor, where that factor is equal to the industry's nominal gross output divided by its nominal value added. That is,

$$MFP_{VA} = \left(\frac{G}{VA}\right) \times MFP_G \tag{3}$$

where MFP_{VA} is multifactor productivity based on value added, MFP_G is multifactor productivity based on gross output, G is nominal gross output, and VA is nominal value added.

In the same way, intra-industry multifactor productivity using intra-industry value added is just

$$MFP_{II} = \left(\frac{G}{G_N}\right) \times MFP_G \tag{4}$$

where MFP_{II} is the intra-industry index, MFP_G is the gross output index, G is nominal gross output and G_N is the nominal gross output of an industry net of intra-industry sales.

Aggregating all industries together using the intra-industry measure of productivity is equivalent to considering all intermediate sales as intra-industry sales and leads to the elimination of all intermediate transactions in the business sector. This is equivalent to producing aggregate productivity measures based on value added. Because of vertical integration, the aggregate measure tends to be larger than the average of the industry measures. As a result, the higher the level of integration shown by the productivity measures, the higher the productivity gains (Durand 1996).

Like labour productivity, multifactor productivity estimates at a high level of industry detail are three years behind the reference year, but current information, based on a projection model, is available for the whole business sector and its major subsectors (Mirotchie 1996). For the multifactor productivity estimates, the model projects current information on the Fisher indices of GDP, capital stock and hours, on the basis of the Laspeyres indices of these variables and dummy trend variables.

A.3.1.3 Availability of results

New results on labour productivity (and related measures) and multifactor productivity (compensation per hour and unit labour cost) announced in Statistics Canada's official news release, *The Daily,* are published twice a year. These estimates are highly current for major sub-sectors of the business sector (one year behind the reference year) but they are three years behind the reference at the industry level. A limited amount of the most current data is provided in the news releases, but the historical series can be accessed from Statistics Canada's CANSIM database or from its Web site at www.statcan.ca. A list of CANSIM matrices can be found in Appendix 4.

Preliminary estimates of labour productivity indices and related measures (unit labour cost and compensation per hour) are generally announced in late April each year (every June for the multifactor productivity estimates). The revisions to the labour productivity estimates (and their related measures), along with the production of more current information at the industry level, are published in November (December for revised multifactor productivity estimates) of the same year, following the release of the input-output tables' results.

A.3.2 Estimation procedures and data sources

A.3.2.1 General overview

In order to produce productivity growth estimates, various data sources from Statistics Canada's survey areas and the System of National Accounts are integrated. In particular, the productivity program requires data from the following:

1. the Input Output Division, which provides the structure of the economy (in terms of industries, the commodities produced and used, and how they change over time) in both current and constant prices that is so essential to the production of aggregate estimates that are built from the ground up at the industry level;

2. the Labour Statistics Division, which provides employment numbers and hours worked to estimate the labour input;

3. the Investment and Capital Stock Division, which provides estimates of year-end net capital stock to estimate capital input; and

4. the Industry Measures and Analysis Division, which produces current estimates of GDP in constant prices, for preliminary estimates of productivity for the three most recent years.

Data that come from these different sources are conceptually adjusted and reconciled for accuracy and consistency. As such, the production of productivity measures serves as an important source of quality control on the various data series that are used in the productivity program. In almost all cases, the data received are transformed into a form that is appropriate for the calculation of productivity estimates. Using the raw data would be inappropriate, or at least would provide productivity estimates that are not as precise as required.

Efforts are made to integrate the data to ensure that measures of outputs and inputs cover the same sectors. For example, industry coverage of the productivity measures includes tenant-occupied housing but does not cover owner-occupied dwellings. Published measures of capital stock do not distinguish between these two activities. Therefore, measures of capital for tenant-occupied housing are derived for the purposes of productivity estimation.

The input-output tables are used to take into account changes in the industrial structure in the weighting procedures that calculate rates of change of outputs and inputs. Calculated rates of change in inputs or outputs are sensitive to the weights that are used to aggregate the 469 commodities that make up outputs or inputs. If these weights are not calculated correctly, estimates of rates of change will be incorrect. Using the input-output tables, the methodology in place allows these weights to change each year (using a Fisher chain weight) so as to keep the industrial structure up to date—both in the calculation of changes in inputs and changes in outputs.[9]

A.3.2.2 Output and input data: Transformation and integration

Statistics Canada's productivity measures are closely linked to the input-output tables. The input-output tables, along with data on hours and capital stock in constant prices, are used to produce the various measures of productivity growth. The production of the annual productivity estimates requires several transformations to the raw data. These transformations involve: a) the choice of the level of aggregation; b) the selection of business sector industries; c) the decision on the valuation of the outputs and inputs; and d) the assumptions on the compensation of primary inputs. Once these transformations are implemented, the resulting data on input and output are integrated with hours and capital stock data.

Transformation of data

Level of detail: Annual input-output data are imported from the input-output tables at the L-level (link) of aggregation from 1961 to the most recent year (usually three years behind the reference year) and include both business and non-business industries. This is the most detailed level for which there is a consistent definition of industries and commodities across all years. All in all, the make (output) and use (intermediate inputs)

[9] Input-output tables in constant prices make use of Laspeyres indices of quantities chained every five years.

matrices of input-output tables have 167 industries (147 non-dummy business industries and 7 dummy business industries for a total of 154 business industries and 13 non-business industries) and 469 commodities excluding indirect taxes and subsidies and compensation of the primary inputs. Indirect taxes and subsidies by commodity and by industry are compiled separately from the intermediate inputs to which they apply.

Compensation of primary inputs includes the following items applicable to incorporated businesses operating in all industries: wages and salaries and supplementary income for the compensation of labour, and other operating surplus for the compensation of capital. Mixed income includes the compensation of labour and capital employed by the unincorporated portion of the business sector.

Coverage of the business sector: Since productivity cannot be measured for non-business industries (general government, private households, non-profit organisations and owner-occupied dwellings) these industries are excluded from both the *make* and the *use* matrices in current and constant prices.[10] The same holds true for dummy industries that are fictitious industries in the input-output tables created to route real commodity consumption to other industries via dummy commodities.

In principle, dummy industries have to be excluded since they have no primary inputs and have intermediate inputs that grow at the same rate as their output, which leave them with zero productivity gains. The exclusion rules are the same as those applied to non-business industries. Therefore, only the 147 non-dummy business industries are retained in the production of productivity estimates.

The owner-occupied portion of residential housing classified in the Finance, Insurance and Real Estate subsector is excluded from the coverage of the business sector for two reasons: a) there is no adequate accounting of labour input of this industry and b) since the U.S. Bureau of Labor Statistics does not account for this industry for the same reasons, it allows Statistics Canada to construct comparable productivity estimates to those of the United States.

Valuation base for outputs, inputs and compensation: All input and output data are adjusted to correspond to prices effectively received from the sale of output and the prices paid as a result of the purchase of inputs. This means that the value of inputs should include taxes and exclude subsidies. Similarly, the value of output is taken net of output taxes and subsidies. To effect this, the value of commodity indirect taxes is distributed over the input and output commodities to which they apply. Subsidies are similarly allocated to the inputs and outputs to which they apply. This means that the concept of GDP used in the productivity estimates is not the same as the one produced by the input-output tables. GDP from the input-output tables is at factor cost, whereas GDP from the productivity program is at basic prices (i.e., GDP at factor cost *plus* indirect taxes on production *minus* subsidies on production).

The following three classes of indirect taxes are considered in the valuation of the inputs: indirect taxes on products, import duties, and indirect taxes on production. The former two apply to the intermediate inputs and the latter applies to the capital compensation. Import duties are included in the import prices of commodities and enter into the intermediate input prices valued at purchaser's prices. The indirect taxes on products

[10] The *make (use)* matrix is a matrix of the input-output tables that reflects the commodities produced (used) by the different industries.

are included in the purchaser's valuation of intermediate commodity input prices. The indirect taxes on production include property taxes as a major component and are considered part of the capital compensation.

Capital income is measured gross of direct income taxes and other non-commodity indirect taxes (mostly property taxes). Similarly, labour income is gross of income taxes.

Compensation of primary inputs: The compensation of the primary inputs in the input-output tables consists of the following variables: a) wages and salaries, b) supplementary labour income, c) mixed income, d) other operating surplus and e) net indirect taxes on production. Wages and salaries and supplementary labour income measure the compensation of paid workers. Other operating surplus is the gross capital income of incorporated businesses and includes profits before taxes, corporate income taxes, depreciation and rents on natural resources. It is computed residually in the input-output accounts as total income minus all other input costs. Net indirect taxes on production include mostly property taxes and are included in the measure of capital income.

Mixed income constitutes the earnings for both capital and labour inputs arising from the unincorporated portion of the business sector and is taken from tax records. Therefore, it includes the labour income of the self-employed and unpaid family workers, both of which are constructed by the productivity program.

The value of labour services of self-employed persons is an imputed value. The imputation is based on the assumption that the value of an hour worked by a self-employed person is the same as the value of an hour worked by an average paid worker in the same industry. This assumption is based on the premise that labour services are contracted on a temporal basis, and a measure of labour compensation should not reflect returns on investment or risk taking. However, an adjustment is made in the case of self-employed persons such as doctors, dentists, lawyers, accountants and engineers. In these cases, the average earnings of paid workers in the same industry tend to be lower than the earnings of the self-employed workers. Although self-employed workers are in the majority in these industries, the imputation of earnings for these workers at the average rate of the paid workers in these industries tends to underestimate the income of the self-employed. In this case, direct evidence on average labour income of these workers is used. Finally, for a given industry, when the imputed income for self-employment produces a higher result than total mixed income, the imputed value is made equal to mixed income.

Unpaid family workers, while not directly compensated for their services, are not a free resource, and their contribution is reflected in the net income of the firm where they are employed. However, no labour income is imputed to unpaid family workers.[11] There is no valid basis for measuring the value of their services, and it is judged that less error is generated by their exclusion from measures of labour compensation than by imputing labour income to them at the same rate as paid workers. The number of unpaid family workers is insignificant in most industries.

Labour income of self-employed and unpaid family workers is then subtracted from mixed income to arrive at the concept of other capital income, a measure of capital compensation of unincorporated businesses used by the productivity program. Other capital income is then aggregated with other operating surplus and net indirect taxes on production to obtain the total capital compensation of incorporated and unincorporated businesses.

[11] Nevertheless, data on hours and employment are available for unpaid family workers.

Integration of hours and capital stock to the transformed input-output tables

The input-output tables in constant prices do not contain data on hours worked and the end-year net capital stock in constant prices. These data undergo several conceptual transformations within the productivity program prior to their integration into the transformed input-output tables.

Labour input: The measurement of labour input requires several refinements to the concept of the head count of employees, the simplest and least differentiated measure of labour input. Such a measure neither recognizes changes in the average work time per employee nor does it reflect the role of self-employed or even differences in labour quality.

The measure of labour input starts with the concept of total jobs, consisting of wage and salary earners, self-employed and unpaid family workers, and then converts units from simple job counts to total hours worked. The rapid increase in non-standard types of employment (part-time, self-employment, etc.) stresses the importance of using hours worked as the unit of labour input in productivity measurement because they bear a closer relationship to the concept of labour services than simple job counts.

The number of hours worked may not be identical to the number of hours paid, mainly as a result of holidays and paid annual sick leave. Hours worked, rather than hours paid, is used to estimate the labour input measure because it is more closely linked to the production process.

At present, estimates of labour input used by Statistics Canada's productivity program implicitly account for differences in the composition of the labour force by industry (quality). Statistics Canada simply aggregates different types of labour at the industry level to produce an industry total. But the growth of the labour input at the level of the business sector and its constituent subsectors is the weighted sum of the number of hours worked by industry where the weights are defined in terms of the industry's share in the total labour compensation. These shares or weights will be comparatively large for industries with above-average wages and relatively small for industries with below-average wages. Assuming that above-average wages reflect above-average skills of the work force, higher weights will be applied to the growth rates of industries with a higher quality of labour. As relative wages increase in an industry, the weights will increase.

Capital input: Capital stock estimates are constructed by using the perpetual inventory method, where successive net capital stock in constant prices is related by the following equation:

$$K_t = I_t + (1-\delta)K_{t-1}, \tag{5}$$

where K_t is the real capital stock at time t, I_t is the real investment, and δ is the (constant) rate of depreciation of the capital stock; δ need not be a constant, but almost always is assumed to be. To construct a capital stock series, one usually starts at an initial period 0 with a measure of the initial capital stock, K_0, and then calculate successive values of K_t by substituting the depreciation rate and the elements of an investment series into (5). By successive backward substitution for K_{t-1} in (5), one can

relate K_t directly to the initial value for the capital stock K_0. K_t becomes a weighted sum of all past levels of investment and the depreciated value of the initial real capital stock

$$K_t = \sum_{i=0}^{t-1} (1-\delta)^i I_{t-i} + (1-\delta)^t K_0. \tag{6}$$

The amount of capital produced from a given stream of investment depends on the depreciation profile that is used. Less capital is produced when the depreciation profiles are relatively steep—where the percentage of value lost in the early years of an asset's life is large.[12] Statistics Canada produces three estimates of capital stock based on three alternative depreciation profiles: the geometric, the delayed and the linear (Statistics Canada 1999). These are derived from:

$$F(\tau, L) = \begin{cases} \delta(1-\delta)^{(\tau-1)} & (\text{geometric}) \\ \frac{L-(\tau-1)}{L-\beta(\tau-1)} - \frac{L-\tau}{L-\beta\tau} & (\text{delayed}) \\ \frac{1}{L} & (\text{linear}) \end{cases} \tag{7}$$

where F represents the value of \$1 of original investment at age τ and L is the length of life. The geometric distribution assumes that the rate of depreciation is a constant. In the geometric function, δ is set equal to $\frac{R}{L}$, where R is an arbitrary constant $(=2)$ and $L(>2)$ the length of life; in the delayed function, β is the curvature parameter which takes the value 0.75 for structures and 0.5 for machinery and equipment. At present, the geometric method is normalized so that the full value of an asset depreciates over its life rather than over an indefinite time span (this is the truncated geometric method).

In addition, the productivity program undertakes several changes to the estimates of capital stock net of geometric depreciation to arrive at a measurement of capital stock that is consistent with the concept of the business sector. The business sector is made up of the private non-residential and the residential components.

Private non-residential capital stock: The following 1980 Standard Industrial Classification for establishments (SIC-E) industries are deleted from the private and public estimates of capital stock published by the Investment and Capital Stock Division to arrive at the private non-residential estimates of capital stock:

- N8100 (Federal Government Service Industries)
- N8200 (Provincial and Territorial Government Service Industries)
- N8300 (Local Government Service Industries)
- O8510 (Elementary and Secondary Education)
- O8520 (Post-Secondary Non-University Education)

[12] While different assumptions about depreciation have a large effect on the level of capital stock, they have much less of an effect on the rate of growth of the capital stock. See Chapter 3.

- O8530 (University Education)

- P8610 (Hospitals)

Residential capital stock: Data on total residential capital stock cover both the tenant-occupied and owner-occupied portions of the economy. Only the former is part of the business sector covered by the productivity program. The breakdown of total residential capital stock between tenant-occupied and owner-occupied portions is made on the basis of gross rent obtained from the input-output tables. The rented portion of the residential sector is then added to the non-residential capital stock to arrive at the business sector's capital stock.

In order to produce capital stock for each industry, capital can be created by simply summing across all asset categories or by deriving a weighted sum using the relative shares of each category in total compensation, where the latter are derived using rental rates of capital. At present time, Statistics Canada uses a simple aggregate across three asset classes (machinery and equipment, buildings, and engineering construction). However, in aggregating capital stock across industries, it weights each industry by its return on capital as described above. Industries with higher cost of capital will implicitly receive a higher weight using this methodology, and changes in relative cost of capital will be reflected in changing weights.

A.3.2.3 On Quality Adjustments

The measurement of multifactor productivity requires estimates of increases in factor inputs. As noted previously, Statistics Canada does so with a measure of hours-worked for labour inputs and real dollars of capital stock on the capital stock. Others (Jorgenson and Griliches, 1967; Jorgenson, 1990) have suggested that adjustments be made to the quality of each of these inputs. For example, this alternate methodology divides hours-worked into various categories (for example, males as opposed to females) and the rates of growth of each are weighted by the relative share of total wages going to each. This procedure gives higher weights to the growth rates of the group earning higher wages—and implicity assumes that higher wages are representative of higher marginal productivity and of higher quality.

This procedure redistributes some of the growth in the multifactor productivity reported here to labour and capital. If multifactor productivity is meant to help us understand the sources of growth, this procedure adds to our information in this regard. For output growth can now be attributed not just to increasing labour but to increasing labour of a certain type. As such this exercice serves to usefully supplement our existing measures and Statistics Canada is working on providing such estimates as a supplement to its normal program.

But it should be noted that these estimates are not without problems. In the first place, differences in wages may not just reflect differences in marginal products. For example, some would argue that male/female wage differentials partially reflect discrimination in labour markets. Ascribing all gender wage differentials to quality differences may be unjustified. And deciding just how much of the differentials to ascribe to real quality differences is not an easy or very precise task.

Second, this approach gradually reduces the residual that multifactor productivity is measuring towards zero—and as such the measure becomes less useful as a measure of technical progress that many users of the data use it for. Nor should we expect the quality corrected measure to be as closely related to measures of industry performance.

Finally, quality adjusted multifactor productivity series would probably have even greater measurement problems than are outlined in Chapter 3.

Despite these shortcomings, Statistics Canada is working on providing new supplementary measures in this area that will be released some time next year.

To construct the growth rate of capital stock, the productivity program makes use of the following sources of information:

1. The private non-residential and residential estimates of capital stock net of geometric depreciation in constant prices produced by the Investment and Capital Stock Division;
2. The information on compensation of capital constructed by the productivity program from the input-output tables.

A.3.2.4 On the 1997 historical revision of the System of National Accounts

Both labour and multifactor productivity measures use data that are periodically revised. About once every five years, the CSNA is rebased to keep up with the evolution of prices in the economy (Jackson 1996). In other words, the constant-price aggregates are recalculated in terms of the prices of a more recent time period. In addition, the System is revamped about once a decade to introduce new accounting conventions and improved methods of estimation. The recent changes to the System also reflect the need to bring the CSNA in line with the 1993 United Nations System of National Accounts (SNA), recommendations that will improve international comparability.[13]

The choice of a base year for the constant price estimates of output and capital stock is arbitrary, but nevertheless important. The *level* of output and capital stock and their components for any particular year can be quite different if the base year is altered. The last rebasing coincided with the release of the GDP estimates for the first quarter of 1996. At that time, the constant price series were shifted from 1986 to 1992 price weights. When the series are recalculated in this manner, the new weights are normally applied from the new base period forward. The estimates for previous years are not normally recalculated using the relative prices of the new base year in the CSNA. Rather, the already calculated constant price estimates for previous years are mechanically linked, or scaled, so as to join up with the new series. Each 'component' series is linked independently and, in some cases, the results are forced to add up through the introduction of 'adjusting entries' series (Statistics Canada 1975: 279). In this way, the growth patterns for earlier years are preserved.

Adjusting entries are calculated for GDP and its subcomponents, like gross capital formation by the CSNA. However, no adjusting entries are presently calculated to estimate capital stock and gross capital formation by the Investment and Capital Stock Division, so that their rebasing changes the growth rate of the capital stock series before the new base year. For this reason, publicly available real GDP and real capital stock estimates are not compatible. The productivity program, however, uses data from these sources that are compatible. The productivity program also uses a chained-type Fisher index in its measure of real output, labour input and capital input to address the problem that arises when rebasing is done periodically.[14] This index is a geometric mean of the chained-weighted Laspeyres and Paasche indices. Changes in this measure are calculated using the weight of adjacent years. These annual changes are 'chained' (multiplied) to form a time series that allows for the continuous incorporation of the effect of changes in relative prices and in the composition of the series over time.

[13] For a comprehensive review of the 1997 historical revision of the CSNA, see Lal (1998).
[14] Before the 1997 historical revision, the program used the Törnqvist chain index.

The 1997 historical revision also made some changes to the previous treatment of several industries in the input–output tables. The main change is the disappearance of the Government Royalties on Natural Resources Industry. In the revised version of the tables, this industry no longer exists and the commodity having the same name is now grouped with other operating surplus (capital income).

A.4 Calculation procedures

A.4.1 Labour productivity

The labour productivity (LP), or output per hour, index between two adjacent years t and $t-1$, is computed as a real value-added Fisher index[15] $\left(Y^F_{i,t/t-1}\right)$ of industry $i\left(i=1,2,\dots,I\right)$ divided by an index of hours worked in that industry $\left(H_{i,t/t-1}\right)$. At the business sector level, we have

$$LP_{i,t/t-1} = Y^F_{i,t/t-1} \div H_{i,t/t-1}. \tag{8}$$

The Fisher index of real value added is computed at the industry level i based on information on prices and quantities of various commodities j produced by this industry. This is accomplished in several steps:

First, the Laspeyres $\left(Y^L_{i,t/t-1}\right)$ and Paasche $\left(Y^P_{i,t/t-1}\right)$ indices of real value added $Y_{i,t/t-1}$, for t and $t-1$ consecutive periods so as to form chain indices, are computed respectively as[16]

$$Y^L_{i,t/t-1} = \sum_{j=1}^{469}\left(\frac{Y_{i,j,t}}{Y_{i,j,t-1}}\right)\cdot\left(\frac{p_{i,j,t-1}\cdot Y_{i,j,t-1}}{\sum_{j=1}^{469} p_{i,j,t-1}\cdot Y_{i,j,t-1}}\right), \tag{9}$$

and[17]

$$Y^{\mathcal{P}}_{i,t/t-1} = \sum_{j=1}^{469}\left(\frac{Y_{i,j,t}}{Y_{i,j,t-1}}\right)\cdot\left(\frac{p_{i,j,t}\cdot Y_{i,j,t-1}}{\sum_{j=1}^{469} p_{i,j,t}\cdot Y_{i,j,t-1}}\right). \tag{10}$$

15 Defined as the geometric mean of the Laspeyres and Paasche chain indices.

16 Recall that real value added is computed as real gross output net of real intermediate inputs.

17 Or alternatively $Y^P_{i,t/t-1} = \left[\sum_{j=1}^{469}\left(\frac{Y_{i,j,t-1}}{Y_{i,j,t}}\right)\cdot\left(\frac{p_{i,j,t}\cdot Y_{i,j,t}}{\sum_{j=1}^{469} p_{i,j,t}\cdot Y_{i,j,t}}\right)\right]^{-1}$.

Second, the Fisher chain index, $Y^F_{i,t/t-1}$, is calculated as

$$Y^F_{i,t/t-1} = \sqrt{Y^L_{i,t/t-1} \times Y^P_{i,t/t-1}}. \tag{11}$$

The Fisher index of real value-added is then constructed at a higher level of industrial aggregation (e.g., the manufacturing sector):

$$Y^F_{t/t-1} = \sum_{i=1} \omega_{it} \cdot Y^F_{i,t/t-1}. \tag{12}$$

where $\omega_{it} = \dfrac{V_{it} - M_{it}}{\left(\sum\limits_{i=1} V_{it} - M_{it}\right)}$ represents the share, in terms of nominal value-added (where V_{it} and M_{it} are, respectively, gross output and intermediate inputs), of the industry i in year t.

The index of hours worked is computed as

$$H_{i,t/t-1} = \frac{\sum\limits_{i=1}^{I} H_{i,t}}{\sum\limits_{i=1}^{I} H_{i,t-1}}. \tag{13}$$

The computation of labour compensation per hour worked parallels the computation of output per hour.

Unit labour costs (ULC), computed as labour compensation (LC) per unit of output, highlights the relationships between unit labour costs, hourly compensations and labour productivity:

$$ULC_{i,t} \equiv \left(\frac{LC_{i,t}}{Y_{i,t}}\right) = \left(\frac{LC_{i,t}}{H_{i,t}}\right) \div \left(\frac{Y_{i,t}}{H_{i,t}}\right). \tag{14}$$

Unit labour cost is identically equal to the ratio of average hourly compensation to labour productivity; thus, unit labour costs will increase when average hourly compensation grows more rapidly than labour productivity.

A.4.2 Multifactor productivity

Like the labour productivity estimates, multifactor productivity estimates make use of a superlative aggregation scheme based on the Fisher chained index on both outputs and inputs across commodities and industries.

Estimates of the Fisher chained index require estimates of prices and quantities at a high level of detail, which is the commodity (j) for both gross output $\left(Q_{ij}\right)$ and intermediate inputs $\left(M_{ij}\right)$, and the industry (i) for capital $\left(K_i\right)$ and hours $\left(H_i\right)$.

The following steps are followed during the construction of the Fisher index for these variables.

A.4.2.1 Output and intermediate inputs

Let p_{ijt} be the price of commodity j produced by the industry i in year t and w_{ijt} the price of the intermediate input j used by the industry i during in year t, whereas Q_{ijt} and M_{ijt} represent their corresponding quantities.

- The Fisher index of output is computed at the industry level i based on information on prices and quantities of various commodities produced or used by this industry. First, the Laspeyres $\left(Q^L_{i,t/t-1}\right)$ and Paasche $\left(Q^P_{i,t/t-1}\right)$ indices of output Q_{it}, for t and $t-1$ consecutive periods are computed respectively as

$$Q^L_{i,t/t-1} = \sum_{j=1}^{469}\left(\frac{Q_{i,j,t}}{Q_{i,j,t-1}}\right)\cdot\left(\frac{p_{i,j,t-1}\cdot Q_{i,j,t-1}}{\sum_{j=1}^{469} p_{i,j,t-1}\cdot Q_{i,j,t-1}}\right), \tag{15}$$

and

$$Q^P_{i,t/t-1} = \sum_{j=1}^{469}\left(\frac{Q_{i,j,t}}{Q_{i,j,t-1}}\right)\cdot\left(\frac{p_{i,j,t}\cdot Q_{i,j,t-1}}{\sum_{j=1}^{469} p_{i,j,t}\cdot Q_{i,j,t-1}}\right). \tag{16}$$

Second, the Fisher index, $Q^F_{i,t/t-1}$, is calculated as

$$Q^F_{i,t/t-1} = \sqrt{Q^L_{i,t/t-1}\times Q^P_{i,t/t-1}}. \tag{17}$$

- The Fisher index of output, $Q^F_{t/t-1}$, is then constructed at a higher level of industrial aggregation (e.g., the manufacturing sector)

$$Q^F_{t/t-1} = \sum_{i=1}\omega_{it}\cdot Q^F_{i,t/t-1}, \tag{18}$$

where $\omega_{it} = \frac{V_{it}}{\sum_{1}^{146} V_{it}}$ represents the share in terms of gross output in nominal prices V_{it} of industry i in year t.[18]

[18] The same approach is developed for the multifactor productivity estimates based on the concept of value added.

A.4.2.2 Capital stock and hours

Much like the estimates of output and intermediate inputs, estimates of the Fisher chain index of capital input and labour input require series on prices and quantities. Series on quantities of labour and capital of industry i in year t are defined in terms of the number of hours h_{it} and the stock of capital in constant prices net of geometric depreciation k_{it}. The price series are constructed implicitly using the ratio of labour compensation W_{it} to the number of hours h_{it} for labour, and the ratio of capital compensation R_{it} (see "Compensation of primary inputs" in section A.3.2.2) to capital stock k_{it}, that is

$$r_{it} = \frac{R_{it}}{k_{it}}, \tag{19}$$

and

$$v_{it} = \frac{W_{it}}{h_{it}}, \tag{20}$$

where r_{it} and v_{it} represent, respectively, the (average) return on capital per unit of capital and the (average) hourly labour compensation. The construction of the Fisher chain index of capital input, $\left(K^F_{i,t/t-1}\right)$, at the industry level proceeds as follows (and similarly for labour):

- First, the Laspeyres $\left(K^L_{i,t/t-1}\right)$ and Paasche $\left(K^P_{i,t/t-1}\right)$ indices of capital input are computed as

$$K^L_{i,t/t-1} = \frac{k_{i,t} \cdot r_{i,t-1}}{k_{i,t-1} \cdot r_{i,t-1}}\,;\; K^P_{i,t/t-1} = \frac{k_{i,t} \cdot r_{i,t}}{k_{i,t-1} \cdot r_{i,t}} \tag{21}$$

The Fisher index of the capital input is then calculated as

$$K^F_{i,t/t-1} = \sqrt{K^L_{i,t/t-1} \times K^P_{i,t/t-1}}. \tag{22}$$

- The Fisher index of capital input, $\left(K^F_{t/t-1}\right)$, at a higher level of aggregation (e.g., manufacturing sector) is calculated as

$$K^F_{t/t-1} = \sum_{i=1}^{122} \omega_{it} \cdot K^F_{i,t/t-1} \tag{23}$$

where $\omega_{it} = \frac{R_{it}}{\sum_{i=1}^{122} R_{it}}$ represents the capital compensation share of the current year t of the industry i in the whole business sector.

The weight ω_{it} for each industry is based on the share of the compensation of each of the primary inputs, which makes the construction of capital input and labour input used for the multifactor productivity indices similar, albeit not identical. In that sense, a partial adjustment for the quality of the primary inputs is obtained as the change in each of these inputs used by an industry is aggregated to the economy-wide level using each industry's share in total compensation as aggregation weights. The capital (labour) weight will be large for industries displaying an above average internal return of capital (labour compensation) and small for those that do not. The weights will increase for those industries whose relative return (wage) increases over time. Some of the change in quality of capital (labour) would then be accounted for, assuming that above-average internal return of capital (labour compensation) reflect above-average 'performance' of capital (labour).

A.4.2.3 Aggregation of the inputs

- The Fisher index of the aggregate input $\left(I^F_{t/t-1}\right)$ is calculated as follows:

$$I^F_{t/t-1} = \bar{s}^K_{t/t-1} \times K^F_{t/t-1} + \bar{s}^L_{t/t-1} \times L^F_{t/t-1}\ , \qquad (24)$$

where $\bar{s}^L_{t,t-1} = \frac{1}{2}\left(s^L_t + s^L_{t-1}\right)$, $\bar{s}^K_{t/t-1} = 1 - \bar{s}^L_{t/t-1}$ and $s^{\iota}_{t/t-1}$ represents the share of the input $\iota\,(\iota = K, L)$ (in terms of its compensation) in the value of output (assumed to be measured in terms of value added).[19]

- The growth rate of the multifactor productivity index $MFP^F_{t/t-1}$ captures the proportional change over time of technical progress (Δ refers to discrete changes in percentage with respect to time):

$$\begin{aligned}\Delta MFP^F_{t/t-1} &= \Delta Q^F_{t/t-1} - \Delta I^F_{t/t-1} \\ &= \Delta Q^F_{t/t-1} - \left(\bar{s}^K_{t/t-1} \times \Delta K^F_{t/t-1} + \bar{s}^L_{t/t-1} \times \Delta L^F_{t/t-1}\right)\ .\end{aligned} \qquad (25)$$

where $Q^F_{t/t-1}$, $K^F_{t/t-1}$ and $L^F_{t/t-1}$ are the Fisher-Ideal indices of output, capital and labour, respectively. In other words, multifactor productivity is simply the growth in output minus the output-share-weighted growth in inputs.

[19] $s^L_t = \frac{\text{Labour compensation}}{\text{nominal output}}$ and s^K_t is obtained residually as a result of the constant returns to scale assumption $s^K_t + s^L_t = 1$.

A.4.3 Labour productivity, multifactor productivity and technology

This part develops the basic algebra of productivity accounting and then relates multifactor productivity measures to single-factor (say labour) productivity indices.

Rewrite $\Delta MFP^{F}_{t/t-1}$ as $\left(\overline{s}^{K}_{t,t-1} + \overline{s}^{L}_{t,t-1}\right) \times \Delta MFP^{F}_{t/t-1}$ and collect terms in (25).[20] This yields:

$$\Delta MFP^{F}_{t/t-1} = \overline{s}^{K}_{t/t-1}\left(\Delta Q^{F}_{t/t-1} - \Delta K^{F}_{t/t-1}\right) - \overline{s}^{K}_{t/t-1}\left(\Delta Q^{F}_{t/t-1} - \Delta L^{F}_{t/t-1}\right). \quad (26)$$

Equation (26) has a straightforward interpretation, since the terms between parentheses represent, respectively, the rate of growth of capital productivity and labour productivity. Equation (26) indicates that multifactor productivity is a weighted average of capital productivity and labour productivity, where the weights are respectively output shares of capital and labour. When capital and labour productivity grow at the same rate, because of Hicks neutral technical change, multifactor productivity $\Delta MFP^{F}_{t/t-1}$ is simply the common rate of capital and labour productivity growth.

To provide an interpretation of elements affecting labour productivity, subtract $L^{F}_{t/t-1}$ from the left-hand side and $\left(\overline{s}^{K}_{t/t-1} + \overline{s}^{L}_{t/t-1}\right) \times \Delta L^{F}_{t/t-1}$ from the right-hand side of (25), and then collect terms. This yields:

$$\left(\Delta Q^{F}_{t/t-1} - \Delta L^{F}_{t/t-1}\right) = \Delta MFP^{F}_{t/t-1} + \overline{s}^{K}_{t/t-1}\left(\Delta K^{F}_{t/t-1} - \Delta L^{F}_{t/t-1}\right), \quad (27)$$

which is interpreted as follows. The growth in labour productivity is the sum of two terms: the effects of technological progress $\Delta MFP^{F}_{t/t-1}$ and the capital-share-weighted change in the capital-to-labour ratio. Rapid gains in labour productivity in the 1960s, for example, were attributable partly to neutral technological progress, but also due to the fact that capital per worker increased substantially, i.e. $\Delta K^{F}_{t/t-1} - \Delta L^{F}_{t/t-1} > 0$. Hence, rapid investment in plant and equipment leads to increases in labour productivity.

Note that this growth accounting framework does not explain why $\Delta K^{F}_{t/t-1} - \Delta L^{F}_{t/t-1}$ was positive; that is a different issue. What (27) reveals is that measured labour productivity is positively related to growth in the capital-to-labour ratio and vice versa.

[20] Recall that $\overline{s}^{K}_{t,t-1} + \overline{s}^{L}_{t,t-1} = 1$.

A.5 International comparisons of productivity growth

A.5.1 Introduction

Since its inception, Statistics Canada's productivity program has established the international comparison of productivity performance as one of its priorities.[21] Attempts over the years to improve the comparability between Canada's productivity measures to those of its major trading partners have been undertaken mainly because comparisons provide information on the competitive position of Canada in foreign trade, which has an important influence on the Canadian economy and employment.

Because statistical concepts and methods vary from country to country, international comparisons of statistical data can be misleading. Differences in sources, concepts and methods used in preparing productivity estimates often lead to substantially different results. This is rightfully worrisome for many users who would like to know which ones they should use in their analysis of current economic conditions.

This section deals with the comparability of productivity estimates from various sources with special emphasis on the estimates produced by the OECD, the U.S. Bureau of Labor Statistics and Statistics Canada. The purpose of this section is not so much to suggest the best estimates but merely to emphasize the differences underlying the productivity measures frequently used by analysts.

A.5.1 U.S. Bureau of Labor Statistics (BLS)

Quarterly and annual estimates of labour productivity along with comparable measures of compensation per hour and unit labour costs are published by the BLS. Data are produced for the business sector, the non-farm business sector, non-financial corporations, the manufacturing sector and its durable and non-durable subsectors.

The BLS also produces different sets of annual multifactor productivity estimates. The multifactor productivity indices for the private business sector and the private non-farm business sectors measure the value-added output per unit of combined labour and capital inputs. Multifactor productivity indices for the manufacturing sector and its 20 constituent industries are calculated as output net of intra-industry transactions (sector output) per combined unit of capital services, labour, energy, materials and services (for more details, see BLS 1997).

The differences between the U.S. and Canadian productivity measures are the following:

1. The BLS uses two business sector concepts in its productivity estimates, both of which are different from their Canadian counterparts. Labour productivity estimates cover a business sector that is similar but not identical to the Canadian concept of the business sector. In addition to government, non-profit institutions and the imputed value of owner-occupied dwellings (all of which are excluded from the Canadian business sector), the U.S. business sector, used for labour productivity estimates, also excludes paid employees of private households. On the other hand,

[21] (...) "In order to shed light on changes in the productivity..., the Dominion Bureau of Statistics has also initiated a number of individual industry studies, mainly in the area of manufacturing. The industries to be studied were selected, in co-operation with other government departments, so as to represent a cross-section of manufacturing, including import-competing industries, export industries and typically domestic industries, and with a view to statistical feasibility and international comparability." (Dominion Bureau of Statistics 1965, forward).

U.S. multifactor productivity estimates cover only the private portion of the whole U.S. business sector as they exclude government business enterprises.

These differences are not expected to yield significant differences in terms of the coverage of the business sector between Canada and the U.S. productivity estimates. For example, government business enterprises represent a negligible portion of the U.S. business sector and their importance has been declining since the 1980s in the Canadian business sector. There are other differences, attributable to institutional factors that may, however, introduce significant differences in the coverage of the business sector in Canada and the United States. Health industries, which are part of the business sector in the United States and the government sector in Canada, are a case in point.

2. Comparisons of GDP estimates between Canada and the United States have been affected by recent changes in the definitions and the statistical methods that were incorporated into the U.S. National Accounts with the completion of their 1999 historical revisions. In the United States, two changes have been made (Parker and Grimm, 2000) to the GDP estimates. First, the method to calculate consumer price changes has been altered. Second, all software expenditures are now counted as an investment.

3. The BLS uses the Fisher Ideal index of real output for both labour and multifactor productivity indices, as does Statistics Canada.

4. The BLS uses the concept of value added only for major sectors' estimates of labour productivity (business sector and non-farm business sector) and multifactor productivity (private business sector, private non-farm business and manufacturing sector). Statistics Canada uses the concept of value added for both industries and sectors' labour productivity and multifactor productivity estimates.

   The BLS also uses the concept of sectoral output (gross output net of intra-industry transactions) for

   - labour productivity estimates of the manufacturing sector, its durable and non-durables components, its three- and four-digit industries; and,

   - multifactor productivity estimates of the manufacturing sector, its 20 two-digit industries and the 9 three- and four-digit industries that are produced. While Statistics Canada also produces comparable estimates to facilitate Canada-United States comparison of multifactor productivity, it also produces estimates of multifactor productivity based on the concept of gross output.

5. The BLS, much like Statistics Canada, makes use of the concept of hours worked.[22] Labour productivity estimates produced by Statistics Canada and the BLS both measure labour as a direct summation of hours at work. Similarly, multifactor productivity indices produced by the BLS for manufacturing industries use the same concept of labour as the labour productivity estimates.

[22] For hours worked, the BLS estimates are benchmarked on establishment surveys rather than household surveys. The establishment surveys are themselves benchmarked on administrative data from state unemployment insurance programs (Farmer and Searson 1995). Statistics Canada estimates are taken primarily but not exclusively from household surveys.

The BLS makes adjustment for labour quality only to its estimates of multifactor productivity based on value added for the private business sector and the non-farm private business sector. In this instance, the hours at work for about one thousand categories of workers are classified by their educational attainment and work experience and are aggregated using an annually chained Törnqvist index. The aggregate growth rate of labour input is therefore a weighted average of the growth rates of each type of worker where the weight assigned to a type of worker is its share of total labour compensation. Because their labour input includes labour quality changes, the BLS measures of labour and productivity are affected by these quality changes.

By contrast, Statistics Canada does not make this direct correction for labour quality. However, its method of deriving Fisher indices at the levels of sub-sectors and the business sector partially captures the adjustment of labour quality. The rate of change in hours worked by each industry is aggregated to the subsector (or sector) level using each industry's share in total labour compensation as weights. These weights will be large for industries that pay above-average wages and small for those that do not. If industries with higher wages have been growing more rapidly, this weighting system will decrease estimates of multifactor productivity relative to alternative aggregation schemes that simply take an unweighted average of the growth rates of all industries.

6. Conceptual differences between Statistics Canada and the BLS in the measurement of capital input are even more important than in the case of labour input. These differences arise from the coverage of capital and the way that detailed data on investment are aggregated by vintage and by asset type.

   BLS includes in its concept of capital, machinery and equipment, residential and non-residential structures, land and inventories at a fairly detailed level by asset type. By contrast, mainly because of paucity in the data, Statistics Canada's productivity program does not exploit the various asset types on residential and non-residential capital stock currently available from the Investment and Capital Stock Division, nor does it make use of land and inventories in the construction of the capital stock.[23]

   BLS's aggregation scheme is based on the 'relative efficiency' for aggregation by vintages and 'rental prices' for the aggregation of different types of assets. The BLS adopts 'age/efficiency' functions that decline gradually during the first few years of an asset's life, and then more rapidly as the asset ages (a concave efficiency schedule).[24] By contrast, Statistics Canada uses a geometric efficiency and

[23] Three major assets are currently available for non-residential capital stock: machinery and equipment, buildings, and engineering construction. For residential capital stock, Statistics Canada currently produces data for the following assets: singles, multiples, mobiles and cottages.

[24] BLS uses a 'hyperbolic' formula to represent the services, s_τ of a τ old asset:

$$\begin{cases} s_\tau = \dfrac{(L-\tau)}{(L-\beta\tau)} & for\ \tau < L \\ s_\tau = 0 & for\ \tau > L. \end{cases}$$

where L is asset's service life, and β is a 'shape' parameter. For $\beta = 1$, this formula yields a gross stock; for $\beta = 0$, it yields a straight line depreciation pattern and for $0 < \beta < 1$, the function declines slowly at first, and then more quickly later. BLS assumes $\beta = 0.5$ for equipment and $\beta = 0.75$ for structures. The formula was implemented assuming the U.S. Bureau of Economic Analysis' service life estimates and also assuming a discard process similar to the one used by BEA.

depreciation pattern. These differences have relatively little effect on cross-country comparisons.

As for the measurement of capital services derived from the capital stock, the BLS applies the rental price and Törnqvist aggregation techniques to detailed categories of asset types. The BLS uses a Törnqvist aggregation with rental prices formulated from Hall-Jorgenson-type tax parameters and a Jorgenson-Griliches type of internal rate of return computed using property income data from the National Income and Product Accounts.[25] In contrast, Statistics Canada sums the three components of capital stock (engineering construction, buildings, and machinery and equipment) for each industry. A Fisher index of capital input is constructed at a higher level of aggregation using capital compensation and capital stock. This methodology implicitly assumes that the capital services yielded by these three assets are equal per dollar of capital stock.

While the BLS still aggregates inputs for its multifactor productivity measures using a Törnqvist chain index, Statistics Canada has switched to the Fisher Ideal index.

A.5.3 Organisation for Economic Co-operation and Development (OECD)

The OECD publishes two sets of estimates that sometimes conflict with one another. One set is produced by the OECD Secretariat and the other by the OECD Statistics Directorate. Both estimates use imperfect measures of inputs because they are interested in cross-country comparisons and cannot get data from some countries that are required for the most precise estimates. By choosing the lowest common denominator available, they provide inaccurate estimates of the true Canadian productivity growth.

Both OECD groups use employment rather than hours-worked to calculate their estimates. This biases the Canadian results downwards.[26]

Equally important, both groups use gross and not net capital stock. It is well recognized that useful capital is net capital. This is the depreciated capital that a firm has available to it. Gross capital stock is the value of capital that was originally purchased and takes no account of the fall in value of capital that occurs over time from use of the capital in production.

Both OECD groups also incorporate another problem. Labour and capital shares of output are needed as weights for the calculation of multifactor productivity. The OECD weights are constant and do not come from Canadian data; they appear to be OECD members' averages.

[25] This implies that property income of industry i in year t is equal to the weighted sum of capital stock, $Y_{i,t} = \sum_j u_{j,i,t} K_{j,i,t} \equiv \sum_j \left(r_{i,t} + \delta_{j,i} + g_{j,i,t} \right) K_{j,i,t}$, where $Y_{i,t}$ is property income assumed to be the residual derived by subtracting labour costs from nominal value added; $K_{j,i,t}$ is the capital stock for the asset j and $u_{j,i,t}$ is the user cost of capital. Data on depreciation rate δ and the capital gain rate g are usually available, but the internal rate of return r is endogenous.

[26] See Chapter 3, "The Precision of Productivity Measures."

In addition to the above problems, the estimate of the OECD Secretariat has three problems:

- First, its measures of outputs and inputs are incompatible. Its measure of output includes owner-occupied dwellings and commercial real estate. But its measure of capital stock does not include the capital that is used for either purpose.

- Second, the measure of inputs and outputs is calculated without taking into account the underlying production structure of the economy. In other words, these estimates are calculated only at the aggregate level and suffer from the type of aggregation bias that was described above.

- Third, its measure of capital stock has been calculated arbitrarily without adequately taking into account Canadian experience. The OECD Secretariat uses an investment series taken from the National Accounts that is not used for the Canadian productivity estimates and ignores the work that has been done on depreciation and discard rates by Statistics Canada's Investment and Capital Stock series.

The OECD Statistics Directorate has created the International Sectoral Data Base (ISDB), which combines a range of data series related primarily to sectoral and industrial value added and their corresponding primary factor inputs (real GDP) used in 14 OECD member countries (OECD 1999). Based on comparable information drawn from sources released by national and international statistical agencies, the database constitutes an important basis for cross-country studies of productivity performance. Therefore, the productivity estimate of the Statistics Directorate follows procedures that are closer to those which have gained international acceptance.

The productivity estimates produced by the ISDB for the 1970 to 1997 period deals with the business sector as a whole as well as with 30 industry groupings covering all industries of 15 member countries. This source is extensively used in the international comparisons of productivity performance.

There are, however, differences between the methodology used by Statistics Canada and that of the ISDB that limit the extent to which results from these two sources may be compared:

- First, the ISDB uses a slightly different definition of the business sector. They include residential housing in their estimates of output and capital stock; Statistics Canada excludes this sector because labour inputs are missing.

- Second, the ISDB starts with individual industry data and aggregates it. However, their aggregation technique uses a Laspeyres weight for only the output, which changes every five years—the same procedure used by the National Accounts of Statistics Canada to produce GDP data. Statistics Canada productivity measures uses an annual Fisher-chained index that updates changes more frequently and is more appropriate for those industries that are experiencing rapid price changes.

- Third, the ISDB does not make any attempt to weight data from underlying industries.

- Fourth, the ISDB uses an index for capital stock that is incompatible with their output index. They choose to use a measure of capital stock which, when rebased, changes all previous growth rates. They use an index of output that does not do so. In contrast, Statistics Canada uses individual industry series for both output and capital whose past growth rates are not changed when rebasing occurs.

Despite these differences, the ISDB estimate is conceptually closer to that of Statistics Canada than that of the OECD Secretariat. At issue is the extent to which the major difference—choice of employment rather than hours worked and use of an inappropriate capital stock—can account for most of the difference between the two series.[27]

Replacing hours worked by employment accounts for most of the difference in the two series. Adding the additional change of gross rather than net capital stock leaves very little difference between the cumulative growth in the two series, despite the other differences that are still embedded in the two estimates. We conclude then that the under estimation of the Canadian productivity performance that has been produced by the Statistics Directorate is almost entirely attributable to their use of these crude measures of inputs.

A.6 Caveats

Measures of labour productivity, multifactor productivity and related measures of costs are useful in investigating the performance of Canadian industries. However, certain characteristics of the productivity and related cost data should be recognized in order to apply them appropriately to specific situations.

First, only the productivity of the business sector is measured. Because of conceptual difficulties, measures of productivity are not available for sectors of the economy, such as government, whose goods and services are not priced by the market.

Second, in several sectors where output is difficult to define, productivity measures are correspondingly weak. Examples are the business services industry, the construction industry and the financial services sector, where output is often an imputed value of labour and other inputs. Thus, the productivity and costs measures for these sectors should be interpreted with caution.

Third, the capital input used in the multifactor productivity framework does not account for land, inventories and natural resources stock, public capital stock and research and development (R&D). Some experimental studies have concluded that natural capital stock, public capital and R&D contribute significantly to multifactor productivity growth.[28] However, these types of inputs pose important challenges in terms of measurement of the quantities and price of services. Nonetheless, as part of an effort to improve the coverage of capital and, accordingly, to increase the comparability between Canadian and U.S. productivity measures, the productivity program has given a priority to estimating land and inventories.

Fourth, measures of productivity account only for resources used in the production process. Unemployed resources available in the economy, which indicate the extent to which the economy is close to its potential capacity, are therefore excluded from the productivity estimates. Nonetheless, comparisons of labour productivity growth and the growth of GDP per capita help to indicate the consequences of not fully employing all labour resources.[29]

Fifth, resources engaged in the production process may not be fully employed, as is often the case in economic downturns. Labour hoarding is a classical example: in response to decreasing demand for its product, an industry may not lay off its employees

[27] See Chapter 3, "The Precision of Productivity Measures."
[28] See Harchaoui (1997), Diaz and Harchaoui (1997) and Mamuneas and Nadiri (1996).
[29] See Chapter 4 on the Canada–United States comparison for a discussion of these issues.

for various reasons such as separation costs and the cost of training new employees should operations expand later on.

A partial adjustment is made to take into account the capacity utilization rate of capital by using the compensation of capital rather than the user cost of capital (Berndt and Fuss 1986). However, at best, this approach only partially dampens the cyclical fluctuations of the productivity growth rates. Since the cyclical fluctuations generally shown by the standard productivity growth measures are often used to make inferences about long-term economic performance, users should be cautious about inferring long-run trends from changes on a yearly basis. To reduce the influence of the cycle on economic performance, users are encouraged to consider a peak-to-peak or a trough-to-trough analysis of productivity growth rates.

A.7 Concluding remarks

This appendix has discussed the development of the Statistics Canada productivity measures program produced for the Canadian business sector and its major constituents (subsectors and industries). It has touched on advances in the literature on productivity measurement and described how these advances have led Statistics Canada to improve the methods it uses and to develop new data series consistent with these advances.

Some further refinements are presently being explored. These advances deal with the quality measurement of the inputs and a broader coverage for the concept of capital that includes land, inventories and exhaustible resources stocks. There are also new lines of research in the productivity front that are worth investigating in the near future. Among these are studies using firm or establishment level data,[30] studies that relax the assumption of constant returns to scale underlying the multifactor productivity framework,[31] and studies designed to expand the scope of productivity measurement to include environmental considerations.

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[30] See Chapter 5 in this publication.
[31] See Chapter 8 in this publication.

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Appendix 2 – Industrial Detail for Productivity Measures and Related Variables

DESMOND BECKSTEAD AND JEAN-PIERRE MAYNARD

The productivity estimates are produced only for input–output accounts (IOA) business sector industries, as defined in Appendix 1 of this publication. The industrial detail within the business sector is based on Statistics Canada's industry classification systems. Since 1981, the system in use has been the 1980 Standard Industrial Classification (SIC).[1] Before this date, the 1960 SIC and 1970 SIC were used. In the IOA, the levels of SIC industries are chosen so as to provide the most detail possible in order to maximize continuity with the previous SIC classifications used. However, the greatest level of detail that is available over time occurs at the L level of aggregation. Data are available at the L-level aggregation of SIC industries for the entire time period from 1961 to the present.

Table A2.1 shows how much industrial detail is provided in the IOA at the three basic levels of productivity output: L (link), M (medium) and S (small). The L-level provides the most detail, and the S-level the least. Each category is defined by the type(s) of establishments involved.

- The business industries, are composed of commercial establishments. These establishments operate on a commercial basis–they sell their goods and services at a price that is designed to cover costs and yield a profit. Included in the business industries are government business enterprises: those "government activities that are conducted on an essentially commercial basis—where the operation is designed to be self-sustaining and where a price is set for the goods and services that is calculated to cover costs" (Statistics Canada 1975).

- The dummy industries are used to differentiate between the various types of markups that are applied to commodities as they are passed from the original producer to the final consumer, even though the goods remain in exactly the same physical condition. For example, the value of the wholesale and retail margins is the difference between the sales and cost of the commodities purchased for resale.

- Services provided by private non-commercial institutions and most services provided by governments are not bought and sold in the market but are rendered to the community without charge and are defined as non-business industries. The non-business industries indicated in Table A2.1 are composed of only non-commercial establishments.

[1] In the near future, all the industry classification in the Input-Output Accounts will be related to the North American Industry Classification System (NAICS).

- Some commercial establishments reside in industries along with non-commercial establishments. These industries are referred to in Table A2.1 as business industries composed of commercial and non-commercial establishments. In industries such as health and education, the non-commercial establishments dominate, while in others (e.g., transportation, radio and television), commercial establishments are the major players.

Table A2.1 Industries at the L , M and S levels

Industrial components	Number of industries	
	Commercial establishments	Non-Commercial establishments
Business industries	L=124 M=29 S=2	–
Dummy industries	L=7 M=3 S=3	
Non-business industries	–	L=4 M=1 S=0
Business industries composed of commercial and non-commercial establishments	L=32 M=25 S=16	
Total economy	L=167 M=58 S=21	

The industrial coverage of the aggregates used in the productivity accounts matches that of the IOA with only one exception, owner occupied dwellings (industry L 136 in Table A2.2 of this appendix). This industry is excluded from productivity analysis because data on labour inputs are not available. This exception aside, labour productivity and unit labour costs are evaluated for business sector L-level industries. Other related variables, such as employment, hours worked and labour compensation, are also evaluated for the business sector industries and for some non-commercial activities.

For the purpose of deriving multifactor productivity growth rates, the inputs of goods and services were taken from the input–output tables at the most detailed level of the L-level industries (167 industries). However, it was not possible to use the inputs or outputs by industry at the L-level because capital stock series can only be produced at a slightly higher level of detail. Thus for the multifactor productivity measures, input–output tables have been aggregated to a special level of aggregation, identified as P, which consists of 123 business sector industries.

Table A2.2 below shows the concordance between the L-level, the 1980 SIC, the M-level and the S-level industries of the IOA, including the special aggregation (P) used for multifactor productivity estimates. The industry names are given for the L-level industries.

Table A2.3 presents the concordance between the L-, M- and S-level industries for all the relevant non-business industries for which we publish employment, hours worked and labour compensation estimates.

Table A2.4 presents all the special aggregations used either for the multifactor productivity or labour productivity estimates. There are 12 special aggregations, including the total business sector, the business sector excluding agriculture, and business sector—goods.

Table A2.2 Concordance between L industries and 1980 SIC, P, M and S industries for the business sector

L	Industry title for the L level	1980 SIC	P	M	S
1	Agricultural and related service	011-023	1	1	1
2	Fishing and trapping	031-033	2	2	2
3	Logging and forestry	041, 051	3	3	3
4	Gold mines	0611	4	4	4
5	Other metal mines	0612-0616, 0619	5	4	4
6	Iron mines	0617	6	4	4
7	Asbestos mines	0621	7	4	4
8	Other non-metal mines (except coal)	0622-0624, 0629	8	4	4
9	Salt mines	0625	9	4	4
10	Coal mines	063	10	4	4
11	Crude petroleum and natural gas	071	11	5	4
12	Quarry and sand pit	081,082	12	6	4
13	Service incidental to mineral extraction	091,092	13	7	4
14	Meat and meat products (except poultry)	1011	14	8	5
15	Poultry products	1012	14	8	5
16	Fish products	102	15	8	5
17	Fruit and vegetable	103	16	8	5
18	Dairy products	104	17	8	5
19	Miscellaneous food product	1051,1052, 1082,1083, 109	18	8	5
20	Feed	1053	18	8	5
21	Vegetable oil mills (except corn oil)	106	19	8	5
22	Biscuit	1071	20	8	5
23	Bread and other bakery products	1072	20	8	5
24	Cane and beet sugar	1081	18	8	5
25	Soft drink	111	21	9	5
26	Distillery products	112	22	9	5
27	Brewery products	113	23	9	5
28	Wine	114	24	9	5
29	Tobacco products	121,122	25	10	5
30	Rubber products	151-159	26	11	5
31	Plastic products	161-169	27	12	5
32	Leather tanneries	1711	28	13	5
33	Footwear	1712	28	13	5
34	Miscellaneous leather and allied products	1713,1719	28	13	5
35	Man-made fibre yarn and woven cloth	181,1829	29	14	5
36	Wool yarn and woven cloth	1821	29	14	5
37	Broad knitted fabric	183	30	14	5
38	Miscellaneous textile products	193, 199	31	15	5
39	Carpet, mat and rug	192	32	15	5
40	Clothing excluding hosiery	243-245, 2491-2493,2495-2499	33	16	5
41	Hosiery	2494	33	16	5
42	Sawmill, planing mill and shingle mill products	251	34	17	5
43	Veneer and plywood	252	35	17	5
44	Sash, door and other millwork	254	36	17	5
45	Wooden box and coffin	256,258	37	17	5
46	Other wood	259	38	17	5
47	Household furniture	261	39	18	5
48	Office furniture	264	40	18	5
49	Other furniture and fixture	269	41	18	5
50	Pulp and paper	271	42	19	5
51	Asphalt roofing	271	43	19	5
52	Paper box and bag	273	44	19	5
53	Other converted paper products	279	45	19	5
54	Printing and publishing	281,283-284	46	20	5
55	Platemaking, typesetting and bindery	282	47	20	5
56	Primary steel	291	48	21	5
57	Steel pipe and tube	292	49	21	5
58	Iron foundries	294	50	21	5
59	Non-ferrous metal smelting and refining	295	51	21	5
60	Aluminum rolling, casting and extruding	296	52	21	5
61	Copper and alloy rolling, casting and extruding	297	53	21	5
62	Other rolled, cast and extruded non-ferrous metal products	299	54	21	5

Table A2.2 Concordance between L industries and 1980 SIC, P, M and S industries for the business sector – Continued

L	Industry title for the L level	1980 SIC	P	M	S
63	Power boiler and structural metal	301-302	55	22	5
64	Ornamental and architectural metal products	303	56	22	5
65	Stamped, pressed and coated metal products	304	57	22	5
66	Wire and wire products	305	58	22	5
67	Hardware, tool and cutlery	306	59	22	5
68	Heating equipment	307	60	22	5
69	Machine shop	308	61	22	5
70	Other metal fabricating	309	62	22	5
71	Agricultural implement	311	63	23	5
72	Commercial refrigeration and air conditioning equipment	312	64	23	5
73	Other machinery and equipment	319	65	23	5
74	Aircraft and aircraft parts	321	66	24	5
75	Motor vehicle	323	67	24	5
76	Truck and bus body and trailer	324	68	24	5
77	Motor vehicle parts and accessories	325	69	24	5
78	Railroad rolling stock	326	70	24	5
79	Shipbuilding and repair	327	71	24	5
80	Miscellaneous transportation equipment	328-329	72	24	5
81	Small electrical appliance	331	73	25	5
82	Major appliances (electric and non-electric)	332	74	25	5
83	Other electrical and electronic product	333, 337, 3392, 3399	75	25	5
84	Record player, radio and television receiver	334	76	25	5
85	Communication and other electronic equipment	335	77	25	5
86	Office, store and business machine	336	78	25	5
87	Communication and energy wire and cable	338	79	25	5
88	Battery	3391		25	5
89	Clay products	351	80	26	5
90	Hydraulic cement	352	81	26	5
91	Concrete products	354	82	26	5
92	Ready-mix concrete	355	83	26	5
93	Glass and glass products	356	84	26	5
94	Miscellaneous non-metallic mineral products	357-359	85	26	5
95	Refined petroleum and coal products	361, 369	86	27	5
96	Industrial chemicals n.e.c.	371	87	28	5
97	Chemical products n.e.c.	372, 379	88	28	5
98	Plastic and synthetic resin	373	89	28	5
99	Pharmaceutical and medicine	374	90	28	5
100	Paint and varnish	375	91	28	5
101	Soap and cleaning compounds	376	92	28	5
102	Toilet preparations	377	93	28	5
103	Other manufacturing	391, 3991, 3992, 3994,3999	94	29	5
104	Jewellery and precious metal	392	95	29	5
105	Sporting goods and toy	393	96	29	5
106	Sign and display	397	97	29	5
107	Floor tile, linoleum and coated fabric	3993	94	29	5
108	Repair construction	401-449	98	30	6
109	Residential construction	401-449	98	30	6
110	Non-residential building construction	401-449	98	30	6
111	Road, highway and airport runway construction	401-449	98	30	6
112	Gas and oil facility construction	401-449	98	30	6
113	Electric power, dams and irrigation construction	401-449	98	30	6
114	Railway, and telecommunication construction	401-449	98	30	6
115	Other engineering construction	401-449	98	30	6
116	Construction, other activities	401-449	98	30	6
117	Air transport and related service	451,452	99	31	7
118	Railway transport and related service	453	100	31	7
119	Water transport and related services	454,455	101	31	7
120	Truck transport	456	102	31	7
121	Urban transit systems	4571	103	31	7
122	Interurban and rural transit systems	4572	103	31	7
123	Miscellaneous transport services	4573, 4575, 458, 459	103	31	7

Table A2.2 Concordance between L industries and 1980 SIC, P, M and S industries for the business sector – Concluded

L	Industry title for the L level	1980 SIC	P	M	S
124	Pipeline transport	461	104	32	7
125	Storage and warehousing	471, 479	105	33	7
126	Telecommunication broadcasting	481	106	34	8
127	Telecommunication carriers	482-483	107	34	8
128	Postal and courier service	484	108	34	8
129	Electric power systems	491	109	35	8
130	Gas distribution systems	492	110	35	8
131	Water systems and other utility n.e.c.	493, 499	111	35	8
132	Wholesale trade	501-599	112	36	9
133	Retail trade	601-692	113	37	10
134	Finance and real estate	701-709, 711-729, 7511, 7512, 759	114	38	11
135	Insurance	731-733	115	39	11
136	Owner occupied dwellings	7513[2]	116	40	11
137	Other business services	771, 772, 777, 779	117	41	12
138	Professional business services	773, 775, 776	117	41	12
139	Advertising services	774	117	41	12
140	Educational service , private	851, 852, 854-859	118	42	13
141	Other health and social service	862, 863, 865-869	119	43	14
142	Accommodation, food and beverage service	911-914, 921, 922	120	44	15
143	Motion picture and video	961-962	121	45	16
144	Other amusement and recreational services	963-969	121	45	16
145	Other personal service	971, 973, 974-979	122	46	16
146	Laundries and cleaners	972	122	46	16
147	Membership organizations (excluding religion) and other services	982-986, 991-999	123	47	16

[2] This is a code specific to the Input-Output Accounts. It is used to express the opportunity cost of owners that occupied their own residence.

Table A2.3 Concordance between the L level industries and the 1980 SIC for the non-business sector industries for which employment and hours worked are provided

L	Industry title	1980 SIC	M	S
1	Service incidental to agriculture	021-023	1	1
2	Fishing and trapping	031-033	2	2
3	Forestry services	051	3	3
103	Miscellaneous manufactured products n.e.c.	3999	29	5
117	Air transport and related service	451-452	31	7
119	Water transport and related services	454-455	31	7
121	Urban transit systems	4571	31	7
123	Other service incidental to transportation	459	31	7
126	Radio and television broadcasting	4811-4813	34	8
131	Water systems and other utility n.e.c.	493, 499	35	8
132	Wholesale trade	501-599	36	9
133	Retail trade	601-692	37	10
134	Finance and real estate	711-729, 741-749, 751, 759	38	11
135	Insurance	731-733	39	11
137	Other business services	771, 777, 779	41	12
138	Professional business services	773, 775, 776,	41	12
140	Educational service , public	851, 852, 854-859	42	13
141	Other health and social service	862-869	43	14
142	Accommodation, food and beverage services	911-914, 921, 922	44	15
143	Motion picture and video	961, 962	45	16
144	Other amusement and recreational services	963-969	45	16
145	Other personal service	971, 973, 974, 979	46	16
147	Membership organizations (excluding religion) and other services	982-986, 991-999	47	16
155	N.B. – P. Religious organizations	981	47	16
160	N.B. – G. Hospitals	861	43	14
162	N.B. – G. University education	853	42	13
164	N.B. – G. Defence services	811	59	22
168	N.B. – G. Federal government service (excluding defence)	812-817	59	22
169	N.B. – G. Provincial and territorial government service	822-827	60	22
170	N.B. – G. Municipal government service	832-837	61	22

Notes: NB - P: non-commercial - private sector, NB - G: non-commercial - government sector, nec: not elsewhere classified

Table A2.4 Special aggregations for multifactor productivity, labour productivity and related variables

Codes	Industry Groupings	P Codes	L Codes
1	Total economy	NA	B & NB (1-135, 137-170)
2	Business sector	1-115, 117-123	1-135, 137-147
3	Business sector - Goods	1-98, 109-111	1-116, 129-131
4	Business sector - Services	99-108, 112-115, 117-123	117-128,132-135, 137-147
5	Non business sector industries	NA	NB (1-3, 103, 117, 119, 121, 123, 126, 131-135, 137, 138, 140-145, 147, 155, 160, 162, 164, 168-170)
6	Non-business sector – Goods	NA	NB (1-3,103, 131)
7	Non-business sector – Services	NA	NB (117, 119, 121, 123, 126, 132-135, 137, 138, 140-145, 147, 155, 160, 162, 164, 168-170)
8	Total economy – goods	NA	B & NB (1-116, 129-131)
9	Total economy – services	NA	B & NB (117-128,132-135, 137-147, 155, 160, 162, 164, 168-170)
10	Business sector excluding Agriculture	2 to 123 excluding 116	2-135, 137-147
11	Non-durables manufacturing industries	14-33, 42-47, 86-93	14-41, 50-55, 95-102
12	Durables – manufacturing industries	34-41, 48-85, 94-97	42-49, 56-94, 103-107

Notes: B: business sector, NB: non-commercial sector, NA: not applicable

Reference:

Statistics Canada. 1975. *A guide to the National Income and Expenditure Accounts: Definitions, Concepts, Sources and Methods*. Catalogue no. 13-549E. 3. System of National Accounts. Ottawa: Minister responsible for Statistics Canada. Occasional.

Appendix 3 – Quality Rating of Productivity Estimates and Related Data

This appendix can be found electronically on our website at :

www.statcan.ca/english/concepts/method.htm

Appendix 4 – Productivity and Related Data in CANSIM

Multifactor productivity	Indices since 1961	CANSIM matrices
Gross output		9456
Gross output excluding intra-industry		9457
Real value added and related data		9458

Labour productivity	Indices since 1946	
Real gross domestic product		9475
Total number of jobs		9476
Annual average number of hours worked for all jobs		9477
Hours worked for all jobs		9478
Total compensation for all jobs		9479
Real gross domestic product per hour worked for all jobs		9480
Total compensation per job		9481
Total compensation per hour worked for all jobs		9482
Unit labour costs		9483

Labour productivity	Absolute values since 1961	
Real gross domestic product		9460
Total number of jobs		9461
Average number of hours worked per year for all jobs		9462
Number of hours worked for all jobs		9463
Total compensation for all jobs		9464
Real gross domestic product per hour worked for all jobs		9465
Total compensation per job		9466
Total compensation per hour worked for all jobs		9467
Unit labour cost		9468
Number of employee jobs		9469
Average number of hours worked per year for employee jobs		9470
Number of hours worked for employee jobs		9471
Labour income per hour worked of employee jobs		9472
Total number of jobs		9473
Hours worked for all jobs		9474

Appendix 5 – Estimates of the Sectorial Sources of Economic Growth in Canada, 1961-1999;

The productivity estimates provided in this publication are limited to the business sector of the economy[1].

This Appendix provides indices and annual growth rates for the multifactor productivity and its components for the business sector and its sub-sectors (business sector goods-producing, business sector services-producing, business sector excluding agriculture and the manufacturing sub-sector). The following components (and derived measures) have been provided for the 1961-1999 period:

1. Output growth rate is measured by the growth rate of real value added

2. The growth rate for capital input

3. The share for capital

4. The capital contribution to output growth is calculated as the product of the (growth rate for) capital input and its share

5. The growth rate for labour input

6. The share for labour

7. The labour contribution to output growth is the product of labour input and its share

8. Multifactor productivity is output growth minus the capital contribution minus the labour contribution

9. A related measure of interest is the growth in the capital/labour ratio – it is given by the capital growth rate minus the labour growth rate.

Multifactor productivity using the value added approach is the difference between the growth rates of output and the growth rate of the combined inputs (labour and capital). In measuring the growth rate of inputs, the growth rate of each input is weighted by its share of output[2].

[1] Details on what constitutes the business sector are provided in Appendix 2.

[2] See Appendix 1 for more detail.

The indices for the multifactor productivity components can be derived directly from their growth rates. Using the business sector growth rate for real value added from Table 2 and its index from Table 1, the following describes how one can be converted to the other:

- The real value added growth rate for 1962 from Table 2 indicates a 7.1% increase from 1961. That is, an index level of 100 in 1961 for real value added was followed by an index level of 100 * (1 + .071) = 107.1. Once the values are available for all years they can be adjusted to a 1992 base by dividing all by the index level for 1992.

- Table 2 shows that the index values for real value added for 1961 is 32.2 and the index for 1962 is 34.5. The ratio of the index for 1962 to that for 1961 is 34.5 / 32.2 = 1.071; hence the growth rate is this ratio minus one: 1.071 - 1 = .071 or 7.1%.

Table 1. Business sector industries – Fisher chain indices of multifactor productivity based on real value added and related data (1992=100)

Year	Real value added	Labour input	Capital input	Combined inputs	Multifactor productivity
CANSIM	I 720329	I 720330	I 720331	I 720332	I 720328
1961	32.2	58.4	29.7	45.5	70.2
1962	34.5	60.4	30.4	46.9	73.0
1963	36.5	61.6	31.2	47.9	75.7
1964	39.1	63.9	32.2	49.6	78.3
1965	41.9	66.7	34.1	52.1	80.1
1966	44.9	70.3	36.5	55.2	81.0
1967	45.8	71.1	39.4	57.2	79.7
1968	48.3	70.8	41.6	58.1	82.7
1969	50.8	72.1	43.2	59.6	84.8
1970	51.9	71.6	44.8	60.1	86.0
1971	54.5	72.6	46.3	61.3	88.5
1972	57.8	74.5	47.6	62.9	91.5
1973	62.6	78.3	49.6	65.9	94.8
1974	64.2	81.2	51.9	68.7	93.3
1975	64.4	80.6	54.4	69.6	92.4
1976	68.8	81.3	56.8	71.0	96.7
1977	71.2	81.9	59.3	72.6	98.1
1978	73.7	84.1	61.6	74.8	98.4
1979	76.8	88.1	64.0	78.1	98.2
1980	78.5	89.5	67.8	80.7	97.2
1981	80.7	92.3	73.5	84.9	94.9
1982	77.4	87.3	78.7	84.2	91.7
1983	79.7	86.7	80.5	84.7	94.0
1984	84.7	89.5	81.5	86.7	97.6
1985	89.7	92.8	83.1	89.3	100.5
1986	92.2	95.6	85.1	91.8	100.4
1987	96.5	99.7	87.2	95.1	101.5
1988	101.0	104.6	90.0	99.1	101.9
1989	103.5	107.2	93.6	102.1	101.3
1990	102.9	106.4	97.3	103.1	99.9
1991	99.5	102.0	99.3	101.0	98.5
1992	100.0	100.0	100.0	100.0	100.0
1993	102.9	101.2	101.6	101.3	101.6
1994	108.9	104.6	103.4	104.1	104.7
1995	113.1	106.7	107.6	107.0	105.8
1996	115.7	108.9	111.3	109.8	105.5
1997	121.8	112.1	113.3	112.6	108.4
1998	125.8	115.4	117.3	116.2	108.5
1999	131.8	119.5	120.7	120.0	110.2

Table 2. Breakdown of annual growth in real value added, business sector industries

Year	(1) Real value added	(2) Capital input	(3) Value capital share	(4) Capital contri-bution	(5) Labour input	(6) Value labour share	(7) Labour contri-bution	(8) Multifactor produc-tivity	(9) Capital/ labour ratio
	Δ %	Δ %	%	Δ % (2) x (3)	Δ %	%	Δ % (5) x (6)	Δ % (1) - (4) - (7)	Δ % (2) - (5)
1962	7.1	2.6	35.3	0.9	3.4	64.7	2.2	4.0	-0.8
1963	5.9	2.5	36.3	0.9	1.9	63.7	1.2	3.7	0.6
1964	7.1	3.3	36.9	1.2	3.7	63.1	2.4	3.5	-0.4
1965	7.2	5.8	36.8	2.1	4.5	63.2	2.8	2.3	1.4
1966	7.0	6.9	36.4	2.5	5.4	63.6	3.4	1.1	1.5
1967	2.1	8.1	35.4	2.9	1.2	64.6	0.8	-1.5	6.9
1968	5.4	5.6	35.2	2.0	-0.4	64.8	-0.3	3.7	6.0
1969	5.1	3.7	35.4	1.3	1.8	64.6	1.2	2.6	1.9
1970	2.2	3.7	35.2	1.3	-0.7	64.8	-0.5	1.3	4.4
1971	5.1	3.4	35.1	1.2	1.4	64.9	0.9	2.9	2.0
1972	6.0	2.8	34.9	1.0	2.5	65.1	1.6	3.4	0.3
1973	8.3	4.1	35.9	1.5	5.1	64.1	3.3	3.6	-1.0
1974	2.6	4.8	37.0	1.8	3.7	63.0	2.3	-1.5	1.1
1975	0.3	4.7	37.0	1.8	-0.7	63.0	-0.4	-1.0	5.4
1976	6.8	4.3	36.3	1.6	0.8	63.7	0.5	4.7	3.5
1977	3.6	4.5	35.9	1.6	0.8	64.1	0.5	1.4	3.7
1978	3.5	3.9	36.6	1.4	2.6	63.4	1.7	0.4	1.3
1979	4.1	3.8	38.3	1.5	4.7	61.7	2.9	-0.2	-0.9
1980	2.3	6.0	39.3	2.4	1.6	60.7	1.0	-1.1	4.4
1981	2.8	8.3	38.8	3.2	3.2	61.2	1.9	-2.4	5.2
1982	-4.1	7.1	37.5	2.7	-5.5	62.5	-3.4	-3.3	12.6
1983	3.0	2.3	38.3	0.9	-0.6	61.7	-0.4	2.4	2.9
1984	6.3	1.2	40.1	0.5	3.2	59.9	1.9	3.9	-1.9
1985	5.9	2.0	40.3	0.8	3.7	59.7	2.2	2.9	-1.7
1986	2.8	2.3	39.3	0.9	3.1	60.7	1.9	0.0	-0.8
1987	4.7	2.5	38.6	1.0	4.3	61.4	2.6	1.1	-1.8
1988	4.6	3.2	38.3	1.2	4.9	61.7	3.0	0.4	-1.7
1989	2.5	4.1	37.4	1.5	2.5	62.6	1.5	-0.6	1.6
1990	-0.5	3.9	36.5	1.4	-0.8	63.5	-0.5	-1.5	4.7
1991	-3.3	2.0	35.0	0.7	-4.1	65.0	-2.7	-1.3	6.2
1992	0.5	0.7	33.9	0.2	-1.9	66.1	-1.3	1.5	2.7
1993	2.9	1.6	34.3	0.6	1.2	65.7	0.8	1.6	0.4
1994	5.8	1.7	36.1	0.6	3.3	63.9	2.1	3.0	-1.6
1995	3.9	4.1	38.1	1.6	2.0	61.9	1.2	1.1	2.1
1996	2.3	3.4	38.9	1.3	2.1	61.1	1.3	-0.3	1.4
1997	5.3	1.8	38.9	0.7	2.9	61.1	1.8	2.8	-1.1
1998	3.3	3.5	38.9	1.4	3.0	61.1	1.8	0.1	0.5
1999	4.8	2.9	38.9	1.1	3.5	61.1	2.2	1.5	-0.7

Table 3. Business sector goods industries – Fisher chain indices of multifactor productivity based on real value added and related data (1992=100)

Year	Real value added	Labour input	Capital input	Combined inputs	Multifactor productivity
CANSIM	I 720351	I 720352	I 720353	I 720354	I 720350
1961	38.9	84.6	33.9	58.6	65.8
1962	42.8	87.5	34.2	60.0	70.8
1963	45.4	88.6	34.8	60.9	74.1
1964	48.5	91.5	35.8	62.8	76.8
1965	52.4	95.4	38.2	66.0	79.0
1966	55.5	100.4	41.2	70.1	78.9
1967	55.7	99.5	45.3	72.2	76.7
1968	59.3	98.5	48.1	73.3	80.6
1969	62.3	98.9	49.6	74.3	83.6
1970	61.5	96.3	51.5	74.0	82.8
1971	64.7	97.2	53.5	75.4	85.5
1972	67.7	98.2	54.8	76.6	88.2
1973	74.2	103.3	56.7	80.1	92.5
1974	74.3	106.0	59.1	82.7	89.7
1975	72.6	102.2	61.5	82.3	88.0
1976	78.4	103.2	63.8	84.0	93.2
1977	81.5	101.7	66.6	84.7	96.2
1978	83.0	102.7	69.1	86.6	95.9
1979	85.4	106.5	71.3	89.6	95.3
1980	85.8	106.6	75.4	91.9	93.2
1981	87.7	107.7	82.4	96.1	90.9
1982	83.2	98.0	89.4	94.7	87.7
1983	86.1	96.0	92.4	95.1	90.5
1984	92.6	98.0	92.8	96.4	96.0
1985	97.5	100.9	93.1	98.1	99.5
1986	98.2	103.2	93.9	99.7	98.6
1987	102.1	108.0	93.7	102.2	100.1
1988	106.5	114.1	94.4	105.9	100.8
1989	108.4	115.9	97.1	108.1	100.5
1990	106.6	111.8	99.5	106.8	99.9
1991	101.2	103.3	100.2	102.1	99.2
1992	100.0	100.0	100.0	100.0	100.0
1993	103.1	99.6	98.0	98.9	104.2
1994	108.6	103.0	97.3	100.5	107.9
1995	112.6	104.5	100.8	103.0	109.3
1996	115.2	105.9	103.3	104.9	109.8
1997	121.7	109.4	104.2	107.1	113.6
1998	124.2	112.5	106.8	110.0	112.9
1999	129.8	115.7	107.5	112.0	116.0

Table 4. Breakdown of annual growth in real value added, business sector goods industries

Year	(1) Real value added	(2) Capital input	(3) Value capital share	(4) Capital contri- bution	(5) Labour input	(6) Value labour share	(7) Labour contri- bution	(8) Multifactor produc- tivity	(9) Capital/ labour ratio
	Δ %	Δ %	%	Δ % (2) x (3)	Δ %	%	Δ % (5) x (6)	Δ % (1) - (4) - (7)	Δ % (2) - (5)
1962	10.1	0.8	36.7	0.3	3.4	63.3	2.1	7.7	-2.5
1963	6.2	1.9	37.6	0.7	1.3	62.4	0.8	4.6	0.6
1964	6.8	2.9	37.7	1.1	3.2	62.3	2.0	3.7	-0.3
1965	8.0	6.4	37.2	2.4	4.3	62.8	2.7	2.9	2.1
1966	6.0	7.9	35.4	2.8	5.2	64.6	3.4	-0.2	2.7
1967	0.3	10.1	34.9	3.5	-0.8	65.1	-0.5	-2.6	10.9
1968	6.5	6.1	35.8	2.2	-1.0	64.2	-0.6	4.9	7.1
1969	5.1	3.2	35.2	1.1	0.3	64.8	0.2	3.7	2.9
1970	-1.3	3.7	34.5	1.3	-2.6	65.5	-1.7	-0.8	6.3
1971	5.2	4.0	34.7	1.4	0.9	65.3	0.6	3.2	3.0
1972	4.6	2.4	37.4	0.9	1.0	62.6	0.7	3.1	1.3
1973	9.5	3.6	40.6	1.4	5.3	59.4	3.1	4.9	-1.7
1974	0.2	4.2	40.8	1.7	2.5	59.2	1.5	-3.0	1.6
1975	-2.3	4.1	39.7	1.6	-3.5	60.3	-2.1	-1.8	7.7
1976	8.0	3.7	39.4	1.5	1.0	60.6	0.6	5.9	2.7
1977	4.0	4.4	40.6	1.8	-1.5	59.4	-0.9	3.1	5.8
1978	1.9	3.8	43.1	1.6	1.0	56.9	0.5	-0.3	2.8
1979	2.8	3.1	45.1	1.4	3.7	54.9	2.0	-0.7	-0.6
1980	0.5	5.8	44.4	2.6	0.1	55.6	0.1	-2.1	5.7
1981	2.2	9.3	42.7	4.0	1.0	57.3	0.6	-2.3	8.3
1982	-5.2	8.4	43.5	3.6	-9.0	56.5	-5.1	-3.7	17.4
1983	3.5	3.4	46.3	1.6	-2.1	53.7	-1.1	3.1	5.4
1984	7.5	0.4	47.4	0.2	2.1	52.6	1.1	6.1	-1.7
1985	5.3	0.3	45.4	0.1	3.0	54.6	1.6	3.6	-2.7
1986	0.7	0.9	44.1	0.4	2.2	55.9	1.2	-0.9	-1.3
1987	4.0	-0.2	44.1	-0.1	4.7	55.9	2.6	1.4	-5.0
1988	4.3	0.8	43.0	0.3	5.6	57.0	3.2	0.7	-4.9
1989	1.8	2.9	41.8	1.2	1.6	58.2	0.9	-0.3	1.3
1990	-1.7	2.4	39.8	1.0	-3.5	60.2	-2.1	-0.5	5.9
1991	-5.0	0.8	38.0	0.3	-7.6	62.0	-4.7	-0.6	8.4
1992	-1.2	-0.2	39.0	-0.1	-3.2	61.0	-1.9	0.8	2.9
1993	3.1	-2.0	41.9	-0.8	-0.4	58.1	-0.2	4.2	-1.6
1994	5.3	-0.7	44.9	-0.3	3.4	55.1	1.9	3.7	-4.1
1995	3.6	3.6	46.9	1.7	1.4	53.1	0.7	1.2	2.2
1996	2.3	2.5	46.9	1.2	1.3	53.1	0.7	0.5	1.2
1997	5.7	0.8	46.9	0.4	3.4	53.1	1.8	3.5	-2.6
1998	2.1	2.5	46.9	1.2	2.8	53.1	1.5	-0.6	-0.3
1999	4.5	0.7	46.9	0.3	2.8	53.1	1.5	2.7	-2.1

Table 5. Business sector services industries – Fisher chain indices of multifactor productivity based on real value added and related data (1992=100)

Year	Real value added	Labour input	Capital input	Combined inputs	Multifactor productivity
CANSIM	I 720362	I 720363	I 720364	I 720365	I 720361
1961	26.6	41.2	25.1	34.9	75.5
1962	27.6	42.6	26.3	36.3	75.2
1963	29.1	43.8	27.2	37.4	77.1
1964	31.3	45.7	28.2	38.9	79.7
1965	33.3	47.8	29.7	40.8	80.9
1966	36.0	50.5	31.3	43.1	83.1
1967	37.5	52.3	33.1	45.0	83.0
1968	39.1	52.5	34.8	45.9	84.9
1969	41.1	54.3	36.3	47.6	85.9
1970	43.6	55.1	37.6	48.6	89.3
1971	45.7	56.2	38.7	49.8	91.6
1972	49.1	58.4	39.9	51.6	95.0
1973	52.6	61.4	41.9	54.2	97.0
1974	55.5	64.4	44.3	57.0	97.3
1975	57.4	65.8	46.8	58.9	97.3
1976	60.5	66.2	49.2	60.1	100.6
1977	62.4	68.3	51.5	62.4	100.1
1978	65.7	71.3	53.6	65.0	101.1
1979	69.4	75.3	56.2	68.5	101.4
1980	72.5	77.6	59.8	71.3	101.6
1981	75.0	81.7	63.9	75.4	99.3
1982	72.8	79.8	67.3	75.6	96.2
1983	74.5	80.4	67.9	76.2	97.7
1984	78.3	83.7	69.5	78.9	99.3
1985	83.3	87.2	72.7	82.3	101.4
1986	87.4	90.6	75.8	85.6	102.2
1987	92.0	94.1	80.3	89.5	103.0
1988	96.6	98.2	85.3	93.9	103.0
1989	99.6	101.2	90.0	97.6	102.1
1990	100.1	102.6	95.2	100.2	99.9
1991	98.2	101.1	98.4	100.2	98.0
1992	100.0	100.0	100.0	100.0	100.0
1993	102.8	102.3	105.4	103.3	99.5
1994	109.1	105.6	110.0	107.0	102.0
1995	113.6	108.2	115.2	110.4	103.1
1996	116.2	111.0	120.5	113.9	102.1
1997	121.9	114.0	124.9	117.4	104.0
1998	127.0	117.6	130.5	121.6	104.6
1999	133.3	122.2	136.4	126.6	105.5

Table 6. Breakdown of annual growth in real value added, business sector services industries

Year	(1) Real value added	(2) Capital input	(3) Value capital share	(4) Capital contri-bution	(5) Labour input	(6) Value labour share	(7) Labour contri-bution	(8) Multifactor produc-tivity	(9) Capital/ labour ratio
	Δ %	Δ %	%	Δ % (2) x (3)	Δ %	%	Δ % (5) x (6)	Δ % (1) - (4) - (7)	Δ % (2) - (5)
1962	3.5	4.6	35.8	1.7	3.5	64.2	2.2	-0.4	1.2
1963	5.5	3.4	36.1	1.2	2.7	63.9	1.7	2.5	0.6
1964	7.5	3.9	35.7	1.4	4.4	64.3	2.8	3.3	-0.5
1965	6.4	5.0	35.4	1.8	4.6	64.6	3.0	1.6	0.4
1966	8.2	5.6	35.4	2.0	5.6	64.6	3.6	2.6	0.0
1967	4.3	5.7	35.4	2.0	3.7	64.6	2.4	-0.1	2.0
1968	4.3	5.1	35.0	1.8	0.3	65.0	0.2	2.3	4.8
1969	5.0	4.2	35.1	1.5	3.5	64.9	2.3	1.2	0.7
1970	6.1	3.7	35.8	1.3	1.4	64.2	0.9	3.9	2.3
1971	5.0	2.9	35.1	1.0	2.0	64.9	1.3	2.7	0.9
1972	7.4	3.2	34.1	1.1	4.0	65.9	2.7	3.7	-0.8
1973	7.1	4.9	32.9	1.6	5.0	67.1	3.3	2.1	-0.1
1974	5.5	5.8	32.5	1.9	4.9	67.5	3.3	0.3	0.8
1975	3.3	5.6	32.7	1.8	2.2	67.3	1.5	0.0	3.4
1976	5.4	5.1	32.1	1.6	0.6	67.9	0.4	3.4	4.4
1977	3.2	4.8	32.3	1.5	3.1	67.7	2.1	-0.5	1.7
1978	5.2	4.1	32.9	1.3	4.3	67.1	2.9	1.0	-0.2
1979	5.7	4.8	32.8	1.6	5.7	67.2	3.8	0.3	-0.9
1980	4.3	6.3	32.5	2.1	3.1	67.5	2.1	0.2	3.3
1981	3.5	6.9	32.0	2.2	5.2	68.0	3.5	-2.3	1.7
1982	-2.9	5.3	32.9	1.8	-2.2	67.1	-1.5	-3.2	7.6
1983	2.4	0.8	33.6	0.3	0.7	66.4	0.5	1.6	0.1
1984	5.1	2.4	32.8	0.8	4.0	67.2	2.7	1.6	-1.7
1985	6.5	4.6	33.3	1.5	4.2	66.7	2.8	2.1	0.4
1986	4.8	4.3	33.5	1.4	3.8	66.5	2.6	0.8	0.5
1987	5.3	5.9	32.8	1.9	3.9	67.2	2.6	0.7	2.0
1988	5.0	6.2	32.4	2.0	4.3	67.6	2.9	0.1	1.9
1989	3.1	5.5	31.8	1.8	3.2	68.2	2.1	-0.8	2.4
1990	0.6	5.7	31.1	1.8	1.4	68.9	0.9	-2.2	4.3
1991	-1.9	3.4	30.7	1.0	-1.5	69.3	-1.1	-1.9	4.9
1992	1.8	1.7	30.6	0.5	-1.0	69.4	-0.7	2.0	2.7
1993	2.8	5.4	31.5	1.7	2.3	68.5	1.6	-0.5	3.1
1994	6.1	4.4	32.4	1.4	3.3	67.6	2.2	2.5	1.1
1995	4.2	4.7	32.1	1.5	2.4	67.9	1.6	1.0	2.3
1996	2.3	4.6	32.1	1.5	2.6	67.9	1.8	-1.0	2.0
1997	5.0	3.7	32.1	1.2	2.8	67.9	1.9	1.9	0.9
1998	4.1	4.5	32.1	1.4	3.1	67.9	2.1	0.6	1.4
1999	4.9	4.6	32.1	1.5	3.9	67.9	2.7	0.8	0.6

Table 7. Business sector excluding agriculture – Fisher chain indices of multifactor productivity based on real value added and related data (1992=100)

Year	Real value added	Labour input	Capital input	Combined inputs	Multifactor productivity
CANSIM	I 720340	I 720341	I 720342	I 720343	I 720339
1961	31.8	55.7	28.4	43.5	72.2
1962	33.7	57.9	29.1	45.0	74.1
1963	35.5	59.2	29.9	46.1	76.3
1964	38.4	61.7	30.9	47.9	79.7
1965	41.3	64.9	32.7	50.5	81.2
1966	44.1	68.6	35.0	53.7	81.6
1967	45.5	69.5	37.9	55.6	81.3
1968	48.0	69.3	40.1	56.7	84.2
1969	50.3	70.7	41.6	58.2	86.1
1970	51.7	70.4	43.2	58.8	87.6
1971	54.2	71.5	44.9	60.2	89.7
1972	58.0	73.6	46.3	62.0	93.3
1973	62.8	77.5	48.2	65.0	96.5
1974	64.9	80.5	50.5	67.7	95.6
1975	64.4	80.0	52.7	68.5	93.8
1976	68.5	80.7	54.9	69.9	97.8
1977	71.1	81.5	57.3	71.4	99.5
1978	73.8	83.7	59.5	73.7	100.1
1979	77.2	87.7	61.8	77.0	100.3
1980	78.9	89.3	65.6	79.6	99.0
1981	80.7	91.9	71.3	83.7	96.2
1982	77.1	86.7	76.7	83.1	92.6
1983	79.6	86.2	78.6	83.7	95.1
1984	84.9	89.0	79.8	85.8	98.9
1985	89.8	92.3	81.5	88.5	101.7
1986	92.0	95.3	83.8	91.2	101.0
1987	96.5	99.5	86.3	94.7	102.1
1988	101.5	104.6	89.2	98.9	102.9
1989	103.7	107.2	93.1	102.0	101.8
1990	102.8	106.4	97.0	103.0	99.8
1991	99.3	102.1	99.1	101.0	98.3
1992	100.0	100.0	100.0	100.0	100.0
1993	102.8	101.2	101.8	101.4	101.4
1994	108.9	104.6	103.6	104.2	104.6
1995	113.1	106.8	107.9	107.3	105.6
1996	115.6	109.0	111.8	110.1	105.1
1997	121.8	112.3	113.9	112.9	108.1
1998	125.8	115.7	117.9	116.6	108.1
1999	131.7	120.0	121.4	120.6	109.5

Table 8. Breakdown of annual growth in real value added, business sector excluding agriculture

Year	(1) Real value added	(2) Capital input	(3) Value capital share	(4) Capital contri-bution	(5) Labour input	(6) Value labour share	(7) Labour contri-bution	(8) Multifactor produc-tivity	(9) Capital/ labour ratio
	Δ %	Δ %	%	Δ %	Δ %	%	Δ %	Δ %	Δ %
				(2) x (3)			(5) x (6)	(1) - (4) - (7)	(2) - (5)
1962	6.1	2.7	36.0	1.0	3.9	64.0	2.5	2.7	-1.2
1963	5.4	2.6	36.6	0.9	2.2	63.4	1.4	3.0	0.4
1964	8.3	3.3	36.5	1.2	4.3	63.5	2.7	4.4	-0.9
1965	7.4	5.9	35.7	2.1	5.2	64.3	3.3	1.9	0.7
1966	6.7	7.1	35.0	2.5	5.7	65.0	3.7	0.5	1.3
1967	3.3	8.2	35.1	2.9	1.2	64.9	0.8	-0.4	7.0
1968	5.4	5.7	35.2	2.0	-0.2	64.8	-0.1	3.5	5.9
1969	4.9	3.8	35.0	1.3	2.0	65.0	1.3	2.3	1.8
1970	2.8	4.0	35.0	1.4	-0.5	65.0	-0.3	1.7	4.4
1971	4.8	3.8	34.7	1.3	1.5	65.3	1.0	2.4	2.3
1972	7.0	3.0	35.2	1.1	2.9	64.8	1.9	4.0	0.1
1973	8.3	4.2	35.8	1.5	5.3	64.2	3.4	3.4	-1.1
1974	3.3	4.7	35.7	1.7	3.9	64.3	2.5	-0.9	0.8
1975	-0.7	4.5	35.3	1.6	-0.7	64.7	-0.4	-1.9	5.2
1976	6.3	4.0	35.3	1.4	0.9	64.7	0.6	4.3	3.1
1977	3.9	4.4	36.1	1.6	1.0	63.9	0.7	1.7	3.4
1978	3.7	3.9	37.7	1.5	2.7	62.3	1.7	0.6	1.2
1979	4.7	3.9	38.7	1.5	4.8	61.3	3.0	0.2	-0.9
1980	2.1	6.1	38.1	2.3	1.8	61.9	1.1	-1.3	4.3
1981	2.3	8.8	36.8	3.2	3.0	63.2	1.9	-2.8	5.8
1982	-4.5	7.5	37.9	2.8	-5.7	62.1	-3.5	-3.8	13.2
1983	3.2	2.5	39.9	1.0	-0.5	60.1	-0.3	2.5	3.1
1984	6.6	1.4	40.0	0.6	3.2	60.0	1.9	4.1	-1.8
1985	5.9	2.2	39.0	0.9	3.7	61.0	2.2	2.7	-1.4
1986	2.5	2.8	38.3	1.1	3.2	61.7	2.0	-0.6	-0.4
1987	4.9	2.9	38.2	1.1	4.4	61.8	2.7	1.1	-1.5
1988	5.2	3.4	37.4	1.3	5.1	62.6	3.2	0.7	-1.7
1989	2.1	4.3	36.3	1.6	2.5	63.7	1.6	-1.0	1.8
1990	-0.9	4.2	34.9	1.5	-0.8	65.1	-0.5	-1.8	4.9
1991	-3.4	2.3	33.9	0.8	-4.1	66.1	-2.7	-1.5	6.3
1992	0.7	0.9	34.3	0.3	-2.0	65.7	-1.3	1.7	2.9
1993	2.8	1.8	36.2	0.6	1.2	63.8	0.8	1.4	0.6
1994	5.9	1.8	38.2	0.7	3.4	61.8	2.1	3.1	-1.6
1995	3.9	4.2	38.8	1.6	2.1	61.2	1.3	1.0	2.1
1996	2.2	3.5	38.8	1.4	2.1	61.2	1.3	-0.4	1.5
1997	5.4	1.9	38.8	0.7	3.0	61.2	1.9	2.8	-1.1
1998	3.2	3.5	38.8	1.4	3.0	61.2	1.8	0.0	0.5
1999	4.7	2.9	38.8	1.1	3.8	61.2	2.3	1.3	-0.8

Table 9. Manufacturing industries – Fisher chain indices of multifactor productivity based on real value added and related data (1992=100)

Year	Real value added	Labour input	Capital input	Combined inputs	Multifactor productivity
CANSIM	I 720373	I 720374	I 720375	I 720376	I 720372
1961	35.8	86.0	38.0	66.7	53.5
1962	40.0	89.2	37.7	68.2	58.5
1963	42.8	91.7	38.3	69.8	61.2
1964	46.9	96.5	39.3	72.8	64.4
1965	51.3	101.5	42.0	77.0	66.8
1966	54.7	106.7	46.0	82.1	66.8
1967	55.8	107.9	51.5	85.7	65.1
1968	59.1	108.1	54.3	87.3	67.8
1969	63.1	109.7	55.3	88.7	71.3
1970	60.7	107.3	57.4	88.3	68.9
1971	64.7	107.4	60.3	89.6	72.4
1972	69.8	110.6	60.5	91.6	76.4
1973	76.3	114.9	62.8	95.1	80.7
1974	77.9	115.8	65.5	96.9	80.8
1975	71.8	111.0	68.3	95.3	75.7
1976	78.1	111.2	69.6	96.0	81.7
1977	81.5	109.8	69.4	95.1	86.1
1978	86.7	113.9	69.6	97.6	89.3
1979	88.5	117.3	69.9	99.7	89.2
1980	86.2	115.8	71.8	99.7	86.9
1981	88.3	114.4	77.8	101.1	87.4
1982	78.9	103.2	83.5	96.1	82.4
1983	83.0	101.0	84.1	94.9	87.8
1984	93.4	103.8	82.0	95.8	97.8
1985	98.3	106.6	80.7	96.9	101.9
1986	99.4	109.7	81.8	99.2	100.6
1987	103.9	113.4	84.4	102.4	101.8
1988	110.2	119.8	87.9	107.6	102.8
1989	112.7	118.8	92.4	109.1	103.7
1990	108.8	112.6	97.7	107.4	101.3
1991	99.1	103.4	99.8	102.2	97.0
1992	100.0	100.0	100.0	100.0	100.0
1993	104.6	99.9	97.1	98.8	105.7
1994	113.3	102.3	94.2	99.0	113.9
1995	118.9	105.7	97.5	102.3	115.7
1996	120.5	108.0	99.9	104.7	114.7
1997	128.9	112.0	101.7	107.7	119.3
1998	133.8	116.5	104.1	111.2	120.0
1999	142.2	120.8	105.5	114.2	124.3

Table 10. Breakdown of annual growth in real value added, manufacturing industries

Year	(1) Real value added	(2) Capital input	(3) Value capital share	(4) Capital contri-bution	(5) Labour input	(6) Value labour share	(7) Labour contri-bution	(8) Multifactor produc-tivity	(9) Capital/ labour ratio
	Δ %	Δ %	%	Δ % (2) x (3)	Δ %	%	Δ % (5) x (6)	Δ % (1) - (4) - (7)	Δ % (2) - (5)
1962	11.8	-0.6	33.7	-0.2	3.8	66.3	2.5	9.5	-4.3
1963	6.9	1.4	34.5	0.5	2.8	65.5	1.8	4.6	-1.5
1964	9.6	2.7	34.8	0.9	5.2	65.2	3.4	5.2	-2.5
1965	9.5	6.9	33.3	2.3	5.2	66.7	3.5	3.8	1.7
1966	6.6	9.6	31.2	3.0	5.1	68.8	3.5	0.1	4.5
1967	2.0	11.9	31.0	3.7	1.0	69.0	0.7	-2.4	10.8
1968	5.9	5.4	31.7	1.7	0.2	68.3	0.1	4.0	5.2
1969	6.8	1.9	29.8	0.6	1.5	70.2	1.1	5.2	0.4
1970	-3.7	3.8	28.8	1.1	-2.2	71.2	-1.6	-3.3	6.0
1971	6.5	5.0	30.2	1.5	0.0	69.8	0.0	5.0	4.9
1972	7.8	0.4	31.9	0.1	3.0	68.1	2.0	5.6	-2.6
1973	9.4	3.9	33.4	1.3	3.9	66.6	2.6	5.6	0.0
1974	2.0	4.2	32.2	1.3	0.8	67.8	0.5	0.2	3.4
1975	-7.8	4.3	29.9	1.3	-4.2	70.1	-2.9	-6.1	8.5
1976	8.7	1.9	29.5	0.6	0.2	70.5	0.2	8.0	1.7
1977	4.4	-0.2	30.5	-0.1	-1.3	69.5	-0.9	5.3	1.0
1978	6.3	0.2	32.1	0.1	3.7	67.9	2.5	3.8	-3.5
1979	2.1	0.4	32.4	0.1	2.9	67.6	2.0	-0.1	-2.5
1980	-2.5	2.8	31.2	0.9	-1.2	68.8	-0.8	-2.6	4.0
1981	2.4	8.3	28.2	2.3	-1.2	71.8	-0.9	0.9	9.5
1982	-10.7	7.3	27.9	2.0	-9.8	72.1	-7.1	-5.7	17.1
1983	5.2	0.7	32.6	0.2	-2.1	67.4	-1.4	6.4	2.8
1984	12.5	-2.5	35.3	-0.9	2.8	64.7	1.8	11.6	-5.3
1985	5.3	-1.6	36.1	-0.6	2.6	63.9	1.7	4.2	-4.2
1986	1.1	1.4	37.5	0.5	3.0	62.5	1.8	-1.3	-1.6
1987	4.5	3.2	39.1	1.2	3.4	60.9	2.1	1.2	-0.2
1988	6.1	4.1	38.9	1.6	5.6	61.1	3.4	1.0	-1.5
1989	2.3	5.1	36.9	1.9	-0.8	63.1	-0.5	0.9	5.9
1990	-3.5	5.7	34.1	2.0	-5.3	65.9	-3.5	-2.0	11.0
1991	-8.9	2.1	31.8	0.7	-8.1	68.2	-5.5	-4.0	10.2
1992	0.9	0.2	32.8	0.1	-3.3	67.2	-2.2	3.1	3.6
1993	4.6	-2.9	37.3	-1.1	-0.1	62.7	-0.1	5.8	-2.7
1994	8.3	-3.0	42.2	-1.3	2.5	57.8	1.4	8.1	-5.5
1995	4.9	3.4	44.4	1.5	3.3	55.6	1.8	1.6	0.1
1996	1.4	2.5	44.4	1.1	2.1	55.6	1.2	-0.9	0.4
1997	6.9	1.8	44.4	0.8	3.7	55.6	2.1	4.1	-1.9
1998	3.9	2.3	44.4	1.0	4.1	55.6	2.3	0.6	-1.7
1999	6.2	1.3	44.4	0.6	3.7	55.6	2.0	3.6	-2.3

Glossary

This glossary provides basic definitions of the terms used in measuring productivity. These terms are essential for a clear understanding of some parts of this publication. Further explanations of many of these terms can be found in the text.

Annual average number of hours worked in all jobs. The annual average of hours worked for jobs in all categories.

Business capital investment. Expenditure on assets having a productive life of more than one year (e.g., machinery and equipment). More precisely, it is an expenditure designed to maintain or improve productive capacity. Business capital investment should not be confused with intermediate inputs, which are consumed or transformed during a relatively short production cycle.

Business sector. Productivity measures exclude all non-commercial activities as well as the rental value of owner-occupied dwellings. Corresponding exclusions are also made to compensation and hours worked. In 1992, business sector GDP accounted for about 71% of the Canadian total. The business sector is further divided into the goods sector and the services sector.

Business sector goods industries. Consists of agriculture, fishing, forestry, mining activities, manufacturing, construction and public utilities.

Business sector services industries. Consists of transportation and storage, communications, wholesale and retail trade, finance, insurance and real estate, and the group formed by community, business and personal services.

Chain indices. Indices calculated for consecutive periods to determine price or volume changes from one period to another. Price and volume variations between successive periods are calculated by combining their short-term movement, i.e., by linking the indices for consecutive periods so as to form chain indices.

Choice of the productivity measures. In calculating productivity, a variety of measures of production (and thus factors of production) can be used: value added, gross output and gross output less intra-industry sales. The choice of a measure of productivity will naturally depend on the user's analytical needs. For example, a measure based on value added is interesting because it not only allows international comparisons, but also eliminates double counting when measuring industrial activity.

Combined inputs. A weighted sum of factors of production, particularly labour and capital. The weighting used to combine labour, capital and sometimes other factors (such as energy, raw materials and services) corresponds to the cost share for each factor with respect to total revenue for the sector.

Factors of production. The economic resources used in a firm's production process. A distinction is usually drawn between two primary factors (labour and capital) and intermediate inputs (energy and raw materials). The term 'inputs' is often used to refer to the factors of production.

Fisher chain index. The geometric mean of the Laspeyres and Paasche chain indices. The Fisher chain index treats two compared periods symmetrically. The real GDP indices to determine variations in quantity for the measurement of productivity are based on Fisher chain indices. These offer the advantage of reducing the variation in the values recorded by the various fixed-base indices.

Fixed capital stock. The stock of machinery, equipment, structures (buildings and engineering construction) and tenant-occupied dwellings.

Full-time equivalent employment (FTE). The number of FTEs is the ratio of the number of hours worked in all jobs to the average number of hours worked per year in full-time jobs. This variable is particularly useful in international comparisons with countries that do not have a statistical device to estimate hours worked in all jobs.

GDP at basic prices. The GDP at factor costs *plus* production taxes *less* subsidies.

GDP at factor costs. The measure of GDP corresponding to the value of combined inputs in labour and capital that must be paid by the producer for use of these factors of production. This measure excludes indirect taxes and subsidies.

Gross domestic product (GDP). The total value of goods and services produced within a country's borders, over a given period, regardless of the nationality of the factors of production.

Hours worked in all jobs. The number of hours worked in all jobs is the annual average for all jobs times the annual average hours worked in all jobs. Hours worked is the total number of hours that a person spends working, whether paid or not. In general, this includes regular and overtime hours, breaks, travel time, training in the workplace and time lost in brief work stoppages where workers remain at their posts. It does not include time lost to strikes, lockouts, annual vacation, public holidays, sick leave, maternity leave or leave for personal needs.

Hours worked in all paid jobs. The average number of paid workers during the year multiplied by the annual average number of hours worked in paid jobs.

Industry activity sector. A group of production units all having the same main activity.

Job-to-population ratio. The ratio of the total number of jobs to overall population.

Labour productivity (GDP per hour worked). The ratio of output to hours worked. Economic performance as measured by labour productivity must be interpreted carefully, as these estimates reflect growth in productivity efficiency and changes in other factors of production (such as capital).

Multifactor productivity. A measure of productivity growth, taking into account many of the resources used in the activity of production. Multifactor productivity growth is estimated residually as the difference between the growth rate of output and the growth rate of combined inputs.

Output. The final product of the activity of production obtained from the combination of resources such as labour, capital, materials, services and energy.

Paid jobs. Jobs held by workers whose base pay is calculated at an hourly rate, or on the basis of a fixed amount for a period of at least a week, or in the form of sales commission, piece rates, mileage allowances and so on.

Productivity index. The ratio of the output index to the combined inputs index; the output and the combined inputs are evaluated at constant prices. Expressing productivity levels using indices facilitates comparison and analysis with respect to a base year.

Real GDP per capita. Often used as an indicator of the evolution of a population's standard of living, it is calculated as the real value of production of goods and services divided by total population.

Real GDP per job. An alternate measure of labour productivity. This is calculated by dividing GDP measured in real terms by the total number of jobs. Since this basic definition of labour productivity does not take into consideration time worked, which varies over time and from worker to worker, it is less accurate than the measure of GDP per hour worked. However, this measure can be useful for comparisons with real GDP per capita and is sometimes used to complement productivity analysis.

Total compensation per hour worked or **hourly compensation.** The ratio of the total compensation for all jobs to the number of hours worked.

Total compensation per job. The ratio of the total compensation for all jobs to the total number of jobs.

Total labour compensation. All payments in cash or in kind made by domestic producers to workers for services rendered—in other words, total payroll. It includes the salaries and supplementary labour income of paid workers, plus an imputed labour income for self-employed workers.

Total number of jobs. An estimate that covers four main categories: paid jobs, work for unincorporated businesses, self-employment, and unpaid family jobs. The last category is found mainly in sectors where family firms are important (agriculture and retail trade in particular). Until recently, self-employment and work for an unincorporated business were grouped together as self-employment.

Unit labour cost. The labour cost per unit of output. It equals labour compensation divided by real GDP. It is also equal to the ratio of labour compensation per hour worked to labour productivity. Unit labour cost increases when labour compensation per hour worked increases more rapidly than labour productivity. It is widely used to measure inflation pressures arising from wage growth.

Value added. A measure of production in the same way as is gross output. However, it has the advantage of eliminating double counting. An industry's value added is equal to its gross output (mainly sales) less its intermediate consumption (energy, raw materials and services). Total value added, over all industries, is equal to the GDP at current price for all industries. In order to compare production between different years, it is necessary to eliminate the effect of price change. Therefore, the change in produced quantities only is estimated from the value added in real terms, that is, the value added of a certain period measured in prices of the other period, usually a previous year. This year called the base year (e.g., 1992), is written as '1992=100'. The double-deflation procedure is used to measure real value added: real intermediate inputs are subtracted from real gross output.

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Productivity Growth in Canada – 2002

John R. Baldwin and Tarek M. Harchaoui
Editors

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Chapter 4—A Comprehensive Revision of the Capital Input Methodology for Statistics Canada's Multifactor Productivity Program

Tarek M. Harchaoui and Faouzi Tarkhani (p. 101)

This chapter outlines the methodology that is used to estimate changes in the amount of capital services used in the production process. The method estimates the user costs of capital for different assets. It then employs these user costs to weight the growth in capital stock of the various assets to produce an estimate of the growth in capital services. The methodology underlying the concept of constructing estimates of capital services recognizes that tangible assets, purchased for the same number of dollars, have different service lives, depreciation rates, tax treatments, and ultimately therefore user costs that are reflected in different marginal products. The methodology makes use of new estimates of depreciation based on age-price profiles of individual assets that are described in Chapter 2. It also provides estimates of capital services under alternate assumptions about the components that enter the formula for the user cost of capital. As a by-product, the chapter ascertains the implications of these new estimates of capital services on a comparison of Canada-U.S. productivity performance.

Chapter 5—Unit Labour Costs and the Competitiveness of Canadian Businesses

Mustapha Kaci and Jean-Pierre Maynard (p. 159)

This chapter describes the measure of unit labour costs that is produced in conjunction with the labour productivity program. The growth in unit labour costs is just the ratio of wage costs per worker divided by the growth in labour productivity. It provides a measure of the cost pressures that arise when remuneration increases faster than labour productivity. The chapter also compares the unit labour costs measure to a more comprehensive statistic that captures other variable costs than just labour costs. Finally, it demonstrates how the measure of unit labour costs can be used to evaluate the competitiveness of particular industries.

Data Appendix—Productivity Series and Related Measures *(p.185)*

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Preface

Statistics Canada has recently reengineered its multifactor (called by some the total factor) productivity measure making changes to the series. In this issue of *Productivity Growth in Canada*, we describe in detail these changes.

Multifactor productivity (MFP) growth is measured as the difference in the rate of growth of outputs minus the rate of growth of inputs. It is positive when the rate of growth of produced output exceeds the rate at which inputs are increased. This index captures a number of factors, such as technological change, the exploitation of scale economies, organizational change and, until the revisions, changes in the 'quality' of inputs.

The quality of inputs has until now been included in the estimate of multifactor productivity because the procedure that was followed simply summed all units of labour, or all units of capital, in an unweighted average and then calculated the growth rate in this aggregate. No attempt was made to recognize that some units of labour or capital are more productive than others.

With this revision, we reestimate both our measure of the growth in labour and the growth in capital recognizing that the units are heterogeneous—that each unit has a different marginal productivity. This procedure is in keeping with the spirit of the existing method of calculating multifactor productivity that already weights the growth in each of the labour and capital aggregates by their respective marginal productivities. The new method simply extends the existing methodology to develop the overall measure of labour growth and the overall measure of capital growth to take into account the marginal productivity differences within each category. This is done by calculating the growth rates of subsets of labour and capital and then creating a weighted average of the growth rate of the total category (labour or capital) that uses as weights a proxy for the relative productivity of each type of labour or each type of asset.

This extension is in keeping with best international practice and with the recommendations of the latest OECD productivity manual. But it adds an additional complexity to the estimation process . In creating the new MFP measure, various decisions had to be made. This monograph outlines the nature of the changes made. It also makes use of the measures to examine specific issues.

The first chapter provides a broad overview of how the new measures can be used to analyze Canada/U.S differences in productivity. The multifactor productivity framework has frequently been used to decompose output growth into different components—the portion of growth that is derived from higher employment, more capital, and the residual measure of multifactor productivity—and to compare them across countries. The new estimates of multifactor productivity growth allow new components to be created and used for comparisons. For example, the new estimate of the growth in capital can be broken down into more detailed asset types. In this chapter, we break out

the information and communications asset component and ask whether it contributes more to growth in Canada than the United States.

Chapters 2 and 4 focus on how the measure of the growth in capital was created. We weight the various asset types by their relative marginal productivity, which we estimate from the capital services derived therefrom. Capital services are just the stock of capital multiplied by the user cost of capital. To measure the user cost of capital, we require, amongst other things, an estimate of the depreciation rate. The second chapter outlines how the depreciation rate was estimated. A special micro dataset on used asset prices that was derived from a Statistics Canada survey was used for this purpose. This chapter examines the procedures that were used and the results obtained.

The fourth chapter discusses the method that was used to develop a measure of the growth in capital. It first describes the assumptions of capital theory upon which we rely. It then outlines the extensions to our asset list that are made. In particular, land and inventories are now included among the assets considered. It then describes the data on depreciation, on rates of return, on tax rates, and capital gains that were required to estimate the user cost of capital of each asset. In several instances, choices among alternatives had to be made. For example, the academic literature alternately chooses the rate of return as the long-term bond rate or the realized rate of return to capital in the industry. The fourth chapter describes the alternatives, the differences in the capital stock growth that results from the use of these alternate methods, and the reasons for the method ultimately chosen.

The third chapter develops the new method that is used to estimate the rate of growth in labour inputs. The rates of growth of different labour types are weighted by their relative marginal productivity—as estimated by their relative wage rates. The chapter describes the assumptions that are required to substantiate this methodology, the labour types that are chosen, and the data used to estimate relative wage rates. As with the capital estimates, alternate assumptions and data sources are available. Each is discussed in turn and the differences from using alternatives are outlined.

The fifth chapter does not fall within the scope of the others that focus on the multifactor productivity program. But it is important because it describes one of the key outputs of the labour productivity program—the measure of unit labour costs. The measure of unit labour costs is produced in association with the estimates of labour productivity (output per worker) and is used by many analysts to forecast wage pressures or to examine the 'competitiveness' of a sector. In essence, this measure compares the rate of growth of unit wages with the growth in labour productivity. The fifth chapter describes what the measure does and how it is derived. It compares unit labour costs to a broader measure that considers not just labour costs but also other variable inputs. It then describes the relationship between changes in Canada's unit labour costs relative to that of the United States and Canada's export growth, showing the close connection of this measure to Canada's success in export markets.

John R. Baldwin
Tarek M. Harchaoui
Editors

1 A Comparison of Canada-U.S. Economic Growth in the Information Age, 1981-2000: The Importance of Investment in Information and Communication Technologies

PHILIP ARMSTRONG, TAREK M. HARCHAOUI, CHRIS JACKSON AND FAOUZI TARKHANI

1.1 Introduction

Information and communication technology (ICT) equipment appears to be almost everywhere—on the desks of executives, on the factory floor, in the classroom, at home, and, these days, even in people's pockets. By all accounts, ICT appears to be rapidly changing the way many enterprises conduct business and communicate. The proliferation of ICT has made the world seem much smaller, as computer-related innovations, such as the Internet, let individuals on opposite sides of the world interact in ways that were unimagined 20 years ago.

The explosion of ICT spending over the last few decades has sparked renewed interest in the role of investment and capital accumulation as sources of economic growth. While productivity growth, capital accumulation, and the impact of technology were topics once reserved for academic debates, the recent success of the U.S. economy has moved them into the popular domain (see Jorgenson and Stiroh, 2000; see also Khan and Santos, 2002 for a Canada-U.S. comparison).

Using revised data on output and capital input, this paper sheds some new light on the changing composition of investment and the growth of capital services in Canada during the 1990s and makes comparisons to the 1980s. In particular, well-tested and familiar methods are employed to estimate annual indices of capital services for the Canadian business sector from 1981 to 2000 and a decomposition into quantity and quality components for broad asset classes, including ICT equipment, is introduced. While much of the recent Canadian economic literature has documented the growing importance of computers, the extent to which ICT and other types of capital have contributed to economic growth in Canada are examined and compared. As a by-product, the underpinnings of the productivity performance of the Canadian and U.S. business sectors over the last two decades are examined using comparable methodologies.

Our approach distinguishes between *capital quantity* growth due to investment, and compositional change of asset types (sometimes referred to as *capital quality* growth) due to substitution between different types of capital assets. Much of the recent investment boom reflects substitution towards high-tech assets as their relative price steadily fell. Quantity and quality decompositions for broad asset classes, such as ICT, other machinery and equipment (made of low-tech equipment), and various types of structures are also introduced.

Our primary conclusion is that the Canadian business sector has experienced a steady and pervasive increase in the growth rate of capital services during the second half of the 1990s. The growth of capital services—including fixed reproducible capital, land, and inventories—has increased from an average annual growth rate of 3.5% for 1981-1988 to 4.2% for 1995-2000.

When sources of Canadian economic growth in output from 1995 to 2000 are examined, the data show that capital and labour continue to make important contributions to overall growth. The increase in the growth of investment, from 1.7% per year over 1981-1988 to 11.9% over 1995-2000, has led to an increase in the contribution of capital services from 1.4% to 1.7% per year between these two periods. Due to strong investment and an increasing input share, high-tech equipment is the only class of fixed reproducible assets that is making a significantly larger contribution to output growth in the second half of the 1990s relative to the 1980s.

During the post-1995 period, the growth contribution of labour input has advanced primarily as a result of the increase in hours worked. The contribution of labour quality declined, a reflection of a falling unemployment rate as more workers with relatively lower marginal products were drawn into the workforce during this period.

The third primary source of growth, multifactor productivity or the famous Solow residual, grew at 0.2% per year on average during the last two decades in Canada, compared to 0.9% per year for the U.S. The acceleration of multifactor productivity in Canada from -0.3% per year over 1988-1995 to 1.0% per year during the post-1995 period (0.5% to 1.3% in the U.S.) suggests considerable improvements in technology and increases in the efficiency of production. While the resurgence in multifactor productivity growth in the post-1995 period has yet to surpass the pre-1973 performance, more rapid multifactor productivity growth is critical for sustained growth at higher rates.

During the post-1995 period, multifactor productivity contributed 21% of the output growth in Canada (27% for the U.S.), up from 6.1% in the 1981-1988 period (26% for the U.S.). Although the recent resurgence in multifactor productivity in both countries does not surpass the pre-1973 performance, it is certainly one of the most important stylized facts of the end of the twentieth century.

The remainder of the paper is organized as follows: Section 1.2 discusses the data sources and the historical trends of investment and capital formation. Section 1.3 analyzes the impacts of these trends on labour productivity and multifactor productivity performance. Section 1.4 concludes the paper.

1.2 Capital and the Aggregate Production Function

1.2.1 General Description of the Data

This paper is based on methodologies recently implemented by the productivity program at Statistics Canada that constructs new Fisher indices of output and inputs for the Canadian business sector that are then used to construct multifactor productivity estimates.

The Fisher output indices use the expenditure based GDP estimates released in the Income and Expenditure Accounts on May 31, 2001, but exclude out-of-scope components such as the government sector, non-profit institutions and the rental on owner-occupied dwellings. Corresponding adjustments are also made to capital stock and hours

worked. The GDP estimates incorporate the capitalization of software expenditures making the Canada-U.S. estimates of economic growth comparable for the first time since October 1999 when the U.S. Bureau of Economic Analysis introduced this change during a comprehensive historical revision to their National Income and Product Accounts.

Statistics Canada's new methodology for estimating the growth of capital services that is appropriate for an aggregate production function analysis is outlined in Chapter 4. The estimation procedure begins with estimates of real investment flows by detailed asset class, then calculates capital stock for each asset class by industry using the perpetual inventory technique. It then estimates the user cost of capital for each industry using Input-Output Tables to derive rates of return at the industry level, micro-economic price data on over 30,000 sales of used assets to obtain depreciation rates (see Chapter 2) and detailed information on tax rates. The growth rates of the stock of capital by asset type of individual industries are then aggregated using the user cost of capital to derive an estimate of the growth in the flow of capital services by industry.

For the analysis in this paper, the wide number of assets used in the productivity program (28 classes) are grouped into three distinct classes. Table 1.1 shows the concordance that produces three broad asset classes—ICT, other machinery and equipment, and structures (which includes inventories and land).[1] This taxonomy not only distinguishes long-lived structures from short-lived equipment, but also information and communications technologies (ICT) from other machinery and equipment.

This paper also uses estimates of labour growth that take into account differences in marginal productivity across labour types (see Chapter 3). Contrary to the method that just sums all hours-worked across all workers, the method that considers differences across labour types sums the growth in hours-worked of different classes of labour weighted by their relative wage rates or their share of labour compensation. Much like the estimates of capital input that capture substitution across asset classes, the approach developed by Jorgenson, Gallop and Fraumeni (1987) for aggregate labour input allows for substitution between various types of labour, e.g., workers cross-classified by education, experience, and other characteristics. This approach allows for a breakdown of the growth of labour input into growth of labour hours and a labour composition or labour quality effect that is similar to the breakdown in capital growth between the straight sum of all capital and changes in its composition.

1.2.2 Capital Stock Estimates in Current Prices

Table 1.2 contains a breakdown of assets into major groupings and the 1981 and 2000 value of capital stock by asset class. The perpetual inventory calculations result in a net stock of fixed reproducible assets of $929 billion in current dollars in 2000, up from $290 billion in 1981. Adding in the estimated value of land and inventories yields a total capital stock of $1.3 trillion in 2000.

[1] The definition of information and communications technologies (ICT) assets, which includes computer hardware, software and telecommunication equipment, is chosen to permit comparisons with the U.S. (see U.S. Bureau of Labor Statistics 2000). There are currently efforts underway within the OECD to define a broader set of ICT commodities which include not only the investment assets used in our definition but also intermediate goods and services, and final demand categories.

Table 1.1 Classification of Capital by Asset Class

Information and Communication Technology
Computers and Office Equipment
Communication Equipment
Software – Own Account
Software – Pre-Packaged
Software – Custom Design

Other Machinery and Equipment
Office Furniture, Furnishing
Household and Services Machinery and Equipment
Electrical Industrial Machinery and Equipment
Non-Electrical Industrial Machinery and Equipment
Industrial Containers
Conveyors and Industrial Trucks
Automobiles and Buses
Trucks (excluding Industrial Trucks) and Trailers
Locomotives, Ships and Boats and Major Replacement Parts
Aircraft, Aircraft Engines and Other Major Replacement Parts
Other Equipment

Structures
Non-Residential Building Construction
Road, Highway and Airport Runway Construction
Gas and Oil Facility Construction
Electric Power, Dams and Irrigation Construction
Railway and Telecommunications Construction
Other Engineering Construction
Cottages
Mobile Homes
Multiple Dwellings
Single Dwellings
Inventories
Land

Table 1.2 Estimates of Net Capital Stock by Asset Class: Canadian Business Sector

	1981 Capital Stock			2000 Capital Stock		
	Value $	Fixed Capital Share (%)	Total Capital Share (%)	Value $	Fixed Capital Share (%)	Total Capital Share (%)
	(millions of current dollars)					
Total Capital Stock	492,588		100.0	1,278,237		100.0
Fixed Reproducible Capital	290,465	100.0		929,409	100.0	
Information, Communication and Technology	11,363	3.9	2.3	59,900	6.4	4.7
Computers and Software	4,444	1.5	0.9	37,493	4.0	2.9
Communication	6,920	2.4	1.4	22,407	2.4	1.8
Other Machinery and Equipment	80,948	27.9	16.4	238,505	25.7	18.7
Structures	198,153	68.2	40.2	631,008	67.9	49.4
Inventories and Land	202,123		41.0	348,828		27.3
Structures, Land and Inventories	400,276		81.3	979,832		76.7

The investment in ICT in constant prices (see Table 1.3) has grown at an average annual rate of 16.2% during the 1981-2000 period, much faster than the other two classes of assets. Despite this rapid growth, however, ICT equipment remains a small share of the business sector's aggregate capital. In 2000, ICT capital stock in nominal terms accounted for 6.4% of fixed reproducible capital, which includes equipment and structures, up from 3.9% in 1981 (see Table 1.2). In our broader definition of capital stock that includes residential assets, land and inventories, ICT assets account for an even smaller share (4.7% in 2000 compared to 2.3% in 1981).

1.2.3 Growth of Investment, Capital Stock, and Capital Services

The growth in Canada's use of capital can be examined using three related data series—an index of the growth in investment, an index of the growth in capital stock (a straight sum of the different assets) and an index of the growth in capital services—from 1981 to 2000. Furthermore, each of these can be decomposed into three components: that arising from investments in ICT, other machinery and equipment, and structures (which include land and inventories).[2]

To better understand aggregate trends, average annual growth rates (in terms of both quantities and prices) are presented in Table 1.3 for each series for the major asset classes and for the entire period 1981-2000, and for three sub-periods: 1981-1988, 1988-1995, and 1995-2000. Growth rates for business sector GDP for the same periods are also reported.

The dominant feature of these estimates is the significant drop of output growth during the early 1990s recession. After growing around 3.3% per year during 1981-1988, output growth fell to 1.6% per year for 1988-1995 and recovered remarkably during the second half of the 1990's to reach 4.9% per year on average. Investment, capital stock and capital services all show similar growth patterns.

1.2.4 Investment

While investment showed a similar growth pattern to growth in output, growth in investment showed more sensitivity to the business cycle. It slowed dramatically from 1.7% per year during 1981-1988 to -0.2% for 1988-1995. However, it surged to 11.9% for 1995-2000, helping to boost GDP growth during this period.

There is substantial variation in the growth rates across asset classes and an accelerating trend toward equipment investment, particularly ICT. Real ICT investment growth was high and rising throughout the last two decades. Despite the GDP slowdown, it was 13.2% per year even during the slow growth in the early 1990s. On the other hand, real investment in non-residential structures and other machinery and equipment dropped to -1.9% and -2.1% per year, respectively, during the period 1988-1995. In recent years, investment in all of the asset classes grew at a much higher pace than during the 1981-1988 period.

The more rapid growth of ICT can be understood by examining the behaviour of relative prices. The rate of inflation of the GDP deflator declined from 4.5% per year (1981-1988) to 2.4% per year (1988-1995) and then to 1.4% per year (1995-2000). The quality-adjusted price of ICT investment goods fell during the same three post-1981 periods (-14.5% to -8.0% to -3.2% per year). Relative to the GDP deflator, ICT prices

[2] See the appendix of Chapter 4 for the differences between these various concepts.

Table 1.3 Average Annual Growth Rates of Investment, Capital Stock, Capital Services and Output: Canadian Business Sector (%)

	Investment Index		Capital Stock Index		Capital Services Index		GDP	
	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity
1981-2000								
GDP	–	–	–	–	–	–	2.9	3.0
All Assets	1.0	3.6	1.0	2.0	4.2	3.4	–	–
ICT	-9.3	16.2	-9.3	12.7	-1.5	21.0	–	–
Other Machinery and Equipment	2.5	2.0	2.5	2.1	5.6	3.4	–	-
Structures	1.5	0.8	1.5	1.7	6.8	2.1	–	–
1981-1988								
GDP	–	–	–	–	–	–	4.5	3.3
All Assets	0.5	1.7	0.5	1.8	6.4	3.5	–	–
ICT	-14.5	11.5	-14.5	8.0	-1.4	21.5	–	–
Other Machinery and Equipment	2.9	2.2	2.9	1.7	7.8	3.7	–	–
Structures	1.7	0.4	1.7	1.9	8.5	2.4	–	–
1988-1995								
GDP	–	–	–	–	–	–	2.4	1.5
All Assets	1.8	-0.2	1.8	1.3	3.7	2.6	–	–
ICT	-8.0	13.2	-8.0	11.5	-2.8	17.5	–	–
Other Machinery and Equipment	2.4	-2.1	2.4	1.2	2.2	1.6	-	–
Structures	2.0	-1.9	2.0	1.3	7.2	1.6	–	–
1995-2000								
GDP	–	–	–	–	–	–	1.4	4.9
All Assets	0.7	11.9	0.7	3.5	1.7	4.2	–	–
ICT	-3.2	27.6	-3.2	21.3	0.3	25.1	–	–
Other Machinery and Equipment	2.0	7.7	2.0	4.1	7.5	5.5	–	–
Structures	0.3	5.6	0.3	2.1	4.1	2.5	–	–

fell at an average of 12.2% per year over the 1981-2000 period. The other categories of investment experienced price increases, but in general they were still lower than those of the GDP deflator.

These investment patterns directly determine the growth of the capital stock. For example, relatively fast ICT equipment investment leads to faster capital stock growth rates and an increase in the capital stock share of equipment.

The long-lived nature of structures, however, means this occurs slowly. The index of real capital stock of ICT equipment, for example, has grown 12.7% per year over the last two decades, while structures grew only 1.7% per year. The share of ICT equipment in the stock of fixed reproducible capital in current dollar terms has increased from 3.9% in 1981 to 6.4% in 2000. This important increase in the value share is due to the large increase in the quantity of ICT capital that more than offset the fall in the price of such capital.

1.2.5 Capital Formation

The indices of the growth of Canadian capital stock and capital services show that the post-1995 period has been one of relatively rapid growth in capital stock. The rate of growth of capital fell from 1.8% per year from 1981-1988 to 1.3% per year from 1988-1995 and rebounded sharply to 3.5% per year from 1995-2000. At the asset level, however, while ICT equipment maintained a sustained growth across all periods, both machinery and equipment and structures experienced a significant slowdown during the 1988-1995 period, followed by a marked recovery in recent years.

Trends in the growth of the capital stock are major determinants of the growth of capital services. The growth of capital services is, however, higher than the growth of capital stock, reflecting the ongoing substitution of short-lived equipment for long-lived structures. This shift in composition is sometimes referred to as changes in capital quality—in the sense that it results from changes in composition that are associated with changes in marginal productivity. All else being equal, a short-lived asset has a higher depreciation rate, relatively higher service price and, therefore, a higher relative marginal productivity since competitive markets equate user capital cost to marginal productivity. As a consequence, the fast growing short-lived assets receive a higher weight in the capital service aggregation compared to their weight for the capital stock (see Chapter 4). For individual asset classes, the results in Table 1.3 show that capital-service growth always exceeds the growth of the capital stock, which implies asset substitution also occurs within asset classes.

These data document an important recovery in the growth rate of Canadian capital services across all asset classes in the post-1995 period. This reflects in large part the rapid growth of investment in the second half of the 1990s for all asset classes. This is an important development since it is the growth of capital services and not the level of capital or investment growth that ultimately affects economic growth in output.

As a point of comparison, it is useful to compare these results to the measure of capital services reported for 1999 by the U.S. Bureau of Labor Statistics (BLS) (2000). For the private business sector, which most closely matches our estimates, BLS (2000) reports capital services growth of 3.8% for all assets for 1981-1999, slightly above our estimate of 3.3% for the same period. This may reflect structural differences between the two countries.

Table 1.4 Decomposition of the Growth in Capital Services by Asset Class: Canadian Business Sector

	Within Quality Effect	Between Quality Effect	Weighted Capital Accumulation	Capital Services Growth
		(annual average growth rates %)		
		1981-2000		
Fixed Capital	0.9	0.3	2.1	3.4
Information and Communication Technology	0.4	0.3	0.5	1.2
Other Machinery and Equipment	0.3	0.1	0.4	0.8
Structures	0.2	-0.1	1.2	1.4
		1981-1988		
Fixed Capital	1.4	0.1	2.0	3.5
Information and Communication Technology	0.6	0.2	0.2	1.0
Other Machinery and Equipment	0.5	0.1	0.3	0.9
Structures	0.3	-0.1	1.4	1.6
		1988-1995		
Fixed Capital	0.7	0.3	1.7	2.6
Information and Communication Technology	0.4	0.3	0.4	1.1
Other Machinery and Equipment	0.1	0.1	0.3	0.4
Structures	0.2	-0.1	1.0	1.1
		1995-2000		
Fixed Capital	0.7	0.6	2.9	4.2
Information and Communication Technology	0.2	0.6	0.8	1.6
Other Machinery and Equipment	0.3	0.1	0.8	1.2
Structures	0.2	-0.1	1.3	1.4

For both countries, the trends are quite similar during the various sub-periods. BLS (2000) reports a decrease in the growth of capital services from 3.9% for 1981-1988 to 2.8% for 1988-1995 and then a recovery to 5.3% for 1995-1999 (3.5%, 2.6% and 4.2%, respectively, for Canada). However, there are marked cross-country differences in the growth of capital services at the asset level. The U.S. ICT equipment capital services grew 17.5% during the 1995-1999 period, up from the 14.5% and 8.5% posted, respectively, during the 1981-1988 and 1988-1995 periods. This is far below the performance experienced by its Canadian counterpart (25.7%, 21.5% and 17.5%, respectively). Although in the U.S., other machinery and equipment and structures recovered in the 1995-1999 period in comparison with the 1988-1995 period, this performance remains below that posted in the previous decade. In contrast, during the 1995-1999 period, Canadian other machinery and equipment and structures experienced their fastest growth of the last twenty years.

1.2.6 Decomposing the Growth in Capital Services

The previous section showed an increase in the growth of capital services for fixed capital and its asset classes but has neither identified nor quantified the sources of this increase in terms of changes in composition of investment within asset classes and between asset classes. This section does just that. It provides a framework that decomposes the growth in capital services into three major components. In this framework, capital services increase for three reasons—substitution towards short-lived, high marginal product assets within asset classes (within quality effect), substitution between asset classes (between quality effect), and the accumulation of capital stock (capital accumulation effect).

The growth of aggregate capital services (the log represents the growth rate) is decomposable as follows (see Ho, Jorgenson and Stiroh 1999):

$$\ell n\left(\frac{\tilde{K}_t}{\tilde{K}_{t-1}}\right) = \sum_j \overline{v}_t^j \ell n\left(\frac{\Delta_t^j}{\Delta_{t-1}^j}\right) + \sum_j (\overline{v}_t^j - \overline{w}_t^j) \ell n\left(\frac{\overline{K}_t^j}{\overline{K}_{t-1}^j}\right) + \sum_j \overline{w}_t^j \ell n\left(\frac{\overline{K}_t^j}{\overline{K}_{t-1}^j}\right). \quad (1)$$

where $\tilde{K}_t$, Δ_t^j, $\overline{K}_t^j$ represent, respectively, aggregate capital services, quality change of the asset class $j =$ ICT, other machinery and structures and the capital stock of the asset class j at period t; $\overline{v}_t^j$ and $\overline{w}_t^j$ are, respectively, average rental cost share and average value share of capital stock for the asset class j at period t.

Each of these three components has a specific economic interpretation. The first term on the right-hand side will be referred to as the "within quality effect," which measures substitution and capital quality growth within distinct asset classes. The second term represents the "between quality effect," which measures substitution between distinct asset classes. The last term is the "capital accumulation effect," which measures capital stock accumulation.

Table 1.4 presents the contribution to the growth in total fixed capital services from each component for 1981-2000 and sub-periods. The decomposition allows us to identify the sources of increase of capital services growth by comparing each component across asset classes and over time. Table 1.4 should be read in the following manner. Consider the 3.4% per year growth of capital services for the 1981-2000 period (last column, first row). This is made up of a 1.2% contribution from ICT, 0.8% from other machinery and equipment and 1.4% from structures. Looked at from the decomposition outlined in equation 1, this 3.4% comes from 0.9% of a within-class effect (substitution across assets within an asset class), 0.3% from a between-class effect (substitution across asset classes), and 2.1% from a capital-accumulation effect (general growth across all asset classes).

The estimates show that at the aggregate level the capital-accumulation effect is the primary source behind the growth of total capital services for all periods. However, this varies across asset classes: the total quality effect (the sum of the within and between quality effect) constitutes the major source behind the growth of ICT capital services for all periods, while the capital-accumulation effect tends to dominate for other machinery and equipment and structures. Substitution across asset groups within an asset class becomes increasingly important over time, particularly for ICT.

For all periods and all asset classes, the total quality effect is primarily driven by the within quality effect. However, the 0.7 percentage point annual increase of capital services between 1981-1988 and 1995-2000, which is mainly attributable to ICT and other machinery and equipment, is mostly driven by the between-effect and the capital-accumulation effect, which increased by 0.5 and 0.9 percentage points per year, respectively.

1.3 A Decomposition of Growth

1.3.1 Framework

The growth of capital services along with the growth in labour input and multifactor productivity are the three primary determinants of the economic growth in output. The final part of this paper evaluates the relative importance of these sources of Canadian economic growth during the period 1981-2000.

This type of growth accounting exercise has a rich history beginning with the seminal work of Solow (1957), who integrated the aggregate production function with national income data to produce an estimate of productivity growth that captured disembodied technical change. Aggregate output Y_t is considered to be produced from capital services $\tilde{K}_t$ and labour services $\tilde{L}_t$. Representing productivity as a 'Hicks-neutral' augmentation A_t of aggregate input, output can be written as:

$$Y_t = A_t F\left(\tilde{K}_t, \tilde{L}_t\right) \tag{2}$$

Under the assumptions of competitive product and factor markets, and constant returns to scale, growth accounting gives the growth of output as the sum of the share-weighted growth of inputs and growth in multifactor productivity:

$$\Delta \ell n Y_t = \bar{s}_{K,t} \Delta \ell n \tilde{K}_t + \bar{s}_{L,t} \Delta \ell n \tilde{L}_t + \Delta \ell n A_t \tag{3}$$

where $\bar{s}_{K,t}$ and $\bar{s}_{L,t}$ are respectively, capital's and labour average share of nominal value-added, $\bar{s}_{K,t} + \bar{s}_{L,t} = 1$, the augmentation factor A_t captures multifactor productivity and Δ refers to a first difference.

Equation (3) has several attractive features. It facilitates the decomposition of the growth in output into the contributions made by labour and capital inputs on one hand, and a residual that is called multifactor productivity growth, on the other hand. It also allows for the quantification of the contributions of different types of capital, such as ICT, to the growth of output.

In addition, rearranging equation (3) enables us to present results in terms of labour productivity growth

$$\Delta \ell n \left(\frac{Y_t}{H_t}\right) = \bar{s}_{K,t} \Delta \ell n \left(\frac{\tilde{K}_t}{H_t}\right) + \bar{s}_{L,t} \left(\Delta \ell n \tilde{L}_t - \Delta \ell n H_t\right) + \Delta \ell n A_t \tag{4}$$

where $\frac{Y_t}{H_t}$ and $\frac{\tilde{K}_t}{H_t}$ are, respectively, output per hour worked and the ratio of capital services to hours worked. This gives the familiar formula that allocates labour productivity growth among three factors. The first is *capital deepening*, the growth in capital services per hour. Capital deepening (also called *capital intensity*) makes workers more productive by providing more capital for each hour of work and raises the growth of

labour productivity in proportion to the share of capital. The second term is the improvement in labour quality, defined as the difference between the weighted growth rates of each category of labour and the growth in the simple sum of hours worked across all worker categories. Reflecting the rising proportion of hours supplied by workers with higher marginal products, labour quality improvement (also called the *labour composition effect*) raises average labour productivity growth in proportion to labour's share. The third term is *multifactor productivity* growth, which increases labour productivity growth on a point-for-point basis. Long-term labour productivity growth arises from three sources: multifactor productivity growth, the contribution of increased capital intensity, and the contribution of shifts in labour composition.

As shown in equation (4), labour productivity (output per hour) can differ from multifactor productivity (output per unit of combined capital and labour inputs) if capital deepening occurs or if labour quality improves.

The remainder of this section provides empirical estimates of the variables in equations (2) through (4). Equations (3) and (4) are then employed to quantify the sources of growth of output and average labour productivity for 1981-2000 and various subperiods.

1.3.2 Empirical Results

This section provides the results associated with equations (3) and (4), which provide two different but related perspectives on the sources of growth: the latter decomposes the sources of labour productivity growth and the former identifies the sources of economic growth of total output. The section commences with an examination of the sources of labour productivity growth.

1.3.3 The Sources of Labour Productivity Growth

The contribution of capital intensity to labour productivity growth equals the growth in the capital-hours ratio multiplied by capital's share of nominal value-added. The contribution of labour composition equals the difference between the growth rates of labour input and of hours worked multiplied by labour's share of nominal value-added. Historically, capital's share has been slightly more than one-third of nominal value-added in the business sector.

Table 1.5 indicates that from 1981 to 2000, labour productivity grew at an annual rate of 1.4% in the business sector. Of the 1.4% growth in labour productivity, 0.2% can be attributed to increases in multifactor productivity, 0.6% to the contribution of capital intensity, and 0.5% to changes in labour composition. Table 1.5 displays a moderate labour productivity increase during the 1980s and early 1990s, and an acceleration of labour productivity growth in the late 1990s. This acceleration reflects the remarkable pick-up in multifactor productivity growth in recent years.

During 1988 to 1995, multifactor productivity decreased -0.3% per year in the business sector. At the same time, the average annual contribution of capital intensity to labour productivity growth increased to 0.9%, and labour composition made a 0.6 percentage point contribution. Labour productivity, therefore, increased 1.2% per year from 1988 to 1995. ICT capital began to play an increasingly important role during this period, contributing 0.4% per year, or more than two-fifths of the contribution of capital deepening to labour productivity growth.

Table 1.5 Annual Average Percentage Point Contribution to Labour Productivity: Canadian Business Sector

	1981-2000	1981-1988	1988-1995	1995-2000
Labour Productivity Growth (annual average growth rate)	1.4	1.3	1.2	1.7
Capital Deepening	0.6	0.6	0.9	0.4
Information and Communication Technology	0.4	0.3	0.4	0.4
Other Machinery and Equipment	0.1	0.1	0.1	0.1
Structures	0.1	0.1	0.3	-0.1
Labour Quality	0.5	0.5	0.6	0.3
Multifactor Productivity (annual average growth rate)	0.2	0.2	-0.3	1.0

Table 1.6 Sources of Economic Growth: Canadian Business Sector

	1981-2000	1981-1988	1988-1995	1995-2000
	(annual average percentage point contribution)			
Output Growth (annual average growth rate)	3.0	3.3	1.5	4.9
Contribution of Capital Services	1.3	1.4	1.0	1.7
Information Communication Technology	0.5	0.4	0.4	0.7
Other Machinery and Equipment	0.3	0.4	0.2	0.5
Structures	0.5	0.6	0.4	0.5
Contribution of Labour Input	1.5	1.7	0.8	2.2
Multifactor Productivity (annual average growth rate)	0.2	0.2	-0.3	1.0
Contribution of Capital Stock	0.9	0.8	0.6	1.4
Contribution of Capital Quality	0.5	0.6	0.4	0.3
Contribution of Labour Hours	1.0	1.2	0.1	1.9
Contribution of Labour Quality	0.5	0.5	0.6	0.3

Table 1.7 The Sources of Economic Growth Canada and U.S., Business Sector

	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.
	1981-1999		1981-1988		1988-1995		1995-1999	
	(annual average percentage point contribution)							
Output (annual average growth rate)	2.9	3.6	3.3	3.9	1.5	2.2	4.8	4.9
Contribution of Labour Input	1.4	1.5	1.7	1.6	0.8	0.9	2.1	1.8
Contribution of Capital Services	1.3	1.2	1.4	1.3	1.0	0.8	1.7	1.8
Contribution of ICT	0.5	0.5	0.4	0.4	0.4	0.3	0.7	1.1
Contribution of Other Machinery and Equipment	0.3	0.3	0.4	0.4	0.2	0.2	0.5	0.4
Contribution of Structures	0.5	0.4	0.6	0.4	0.4	0.2	0.6	0.4
Multifactor Productivity (annual average growth rate)	0.2	0.9	0.2	1.0	-0.3	0.5	1.0	1.3

U.S. data are taken from the U.S. Bureau of Labor Statistics (2000).
Numbers may not add due to rounding.

During 1995-2000, labour productivity grew 1.7% per year in the business sector, 0.5 percentage points faster than during the 1988-1995 period. This acceleration is attributed entirely to the remarkable resurgence of multifactor productivity growth, which increased by more than one percentage point. Continuing the trend in substitution of ICT for other forms of capital, ICT capital accounted for the whole contribution of capital deepening to labour productivity growth. Growth in labour quality slowed relative to the growth in hours in the 1995-2000 period.

1.3.4 The Sources of Economic Growth

Using the framework developed above, the capital and labour inputs are combined with output data to estimate the components of equation (3) to quantify the sources of economic growth in output from 1981-2000. In addition to the standard contribution of aggregate capital services, the analysis also examines the contribution of each broad asset class to total growth.

Results are reported in Table 1.6 and should be read in the following manner. In the second column, for the period 1981-1988, output grew at 3.3% per year, of which aggregate capital services contributed 1.4%, labour input 1.7%, and multifactor productivity 0.2%. The 1.4% capital contribution is from the growth rate of capital services multiplied by the $\overline{s}_{K,t}$ share and may also be decomposed into a 0.8% contribution of capital accumulation and 0.6% of quality change. Similarly, the 1.7% labour input contribution can be decomposed into a 1.2% contribution from increased hours worked and a 0.5% contribution from quality change due to substitution toward more highly educated workers.

For 1995-2000, output grew 4.9% per year, capital services contributed 1.7 percentage points, labour input contributed 2.2 percentage points, and multifactor productivity contributed 1.0 percentage points.

As reported above, there has been an increase in the contribution of capital services during 1995-2000 since the growth contribution increased to 1.7% from 1.4% per year over 1981-1988. ICT shows the largest increase in the contribution of capital services between the two periods, nearly doubling from 0.4% to 0.7%. In addition, the most recent estimates show an increase in the growth of multifactor productivity that is above any rate since 1981.

1.3.5 Canada-U.S. Comparison of Multifactor Productivity Growth

An examination of Table 1.7 for both the Canadian and U.S. business sectors over 1981-1999, the most recent period for which U.S. multifactor productivity estimates are available, reveals that Canada's multifactor productivity grew at 0.2% per year on average, compared to 0.9% per year for the U.S. This productivity gap between the two countries is largely attributable to Canada's relatively modest multifactor productivity performance from 1981 to 1995. The lack of multifactor productivity gain in Canada from 1981 to 1995 (0.0% compared with 0.7% in the U.S.) reflects a 2.4% increase in output (3.3% in the U.S.) and a 2.4% increase in combined inputs of capital and labour (2.5% in the U.S.).

In the late 1990s, output grew at an average annual rate of 4.8% in Canada (4.9% for the U.S.), a 3.2 percentage point increase relative to the early 1990s (2.7 percentage points for the U.S.). Multifactor productivity growth makes an important recovery to 1.0% in

Canada (1.3% for the U.S. as well), while capital services' contribution to growth recovered to 1.7% in Canada (1.8% in the U.S.), and labour's contribution rebounded to 2.1% points (1.8% for the U.S.).

Multifactor productivity growth is the source of 21% of output growth in Canada (27% in the U.S.), up from 6.1% in the 1981-1988 period (26% for the U.S.). The acceleration in multifactor productivity growth in Canada and the U.S. is perhaps the most remarkable feature of the data. Its acceleration in Canada from -0.3% per year to 1.0% per year (0.5% to 1.3% in the U.S.) between 1988-1995 and 1995-1999 suggests considerable improvements in technology and increases in the efficiency of production. While the resurgence in multifactor productivity growth in the post-1995 period has yet to surpass the pre-1973 performance, more rapid multifactor productivity growth occurred in the last part of the 1990s.

1.4 Conclusion

This paper has documented the evolution of the sources of economic growth of the Canadian business sector. It finds that the growth in output of the Canadian business sector in the post-1995 period has been substantially above the earlier part of the decade and of the previous decade. In addition, after almost two decades of lacklustre performance, the productivity statistics, beginning in 1995, have begun to reveal the impact of increasing capital formation in ICT technologies. Progress in ICT is driving down relative prices of computers, software, and communication equipment and inducing investment in these assets by firms (12.2% per year growth on average during the 1981-2000 period).

The paper also examines the pattern of growth in capital services in terms of both quantity and quality components. It distinguishes between capital quantity growth due to investment, and capital quality growth due to substitution between different types of capital assets. Much of the recent investment boom has been associated with substitution across assets as the relative price of high-tech assets steadily fell. Capital 'quality' grew over the 1981-2000 period at 1.2% per year on average, of which 75% was due to changes within asset classes.

In terms of the sources of the 3.3% annual average growth over the 1981-1988 period, capital input contributed 1.4% per year (0.6% for quality and 0.8% for capital quantity), labour input contributed 1.7% per year (1.2% for hours and 0.5% for labour quality). This is somewhat similar to the 1995-2000 period, when capital input at 1.7% contributed less than labour input at 2.2% per year to output growth.

In both countries, ICT is the largest contributor to growth within capital services, during the late 1990s, followed closely by structures in Canada. But the contribution of ICT in Canada is lower than in the U.S.

What is even more remarkable about the post-1995 period, compared to the previous periods, is the recovery in the multifactor productivity performance, posted at 1.0% per year in Canada and 1.3% in the U.S. (compared to 0.2% and 1.0%, respectively, for the 1981-1988 period).

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2 An Alternative Methodology for Estimating Economic Depreciation: New Results Using a Survival Model

GUY GELLATLY, MARC TANGUAY AND BEILING YAN

2.1 Introduction

Studies of asset depreciation are illuminating, in part, because they enable national accountants to better characterize the evolution of an economy's productive capacity. Base indicators of economic performance, such as multifactor productivity estimates, depend on the growth of the economy's stock of capital assets. In the standard perpetual inventory framework, the stock of capital available to economic agents in any current period is simply the sum of current investment and cumulative net investment in past periods (i.e., gross accumulated capital stock less depreciation). Different depreciation profiles can affect how this cumulative stock of capital is discounted, and may give rise to discordant statistical impressions of how productively the economy is transforming inputs into outputs.

An equally illuminating vantage point to evaluate the impact of asset depreciation is by studying its effect on investment behaviour. Commenting on the consequences of the rules used for tax depreciation, Hulten and Wykoff (1981, p. 82) make the observation that "depreciation lives, without some factual basis, can lead to potentially serious distortions in the incentives to invest in various types of assets." Depreciation, and perceptions thereof, have substantial impacts on the economic system.

This chapter uses new micro-level data on used-asset prices to estimate patterns of economic depreciation. We develop depreciation profiles and life estimates for 25 different machinery and equipment assets and 8 structures. As a final exercise, we use our estimation framework to produce perpetual inventory estimates of the capital stock. At various stages of the analysis, we compare our econometric results that are derived *ex post* from price information to a range of *ex ante* results based on estimates of service life and geometric accounting techniques.

Our principal objectives in this chapter are, first, to develop a more comprehensive profile of how asset values decline at different stages of service life, and second, to ask whether the existing stock of techniques and assumptions, commonly used to produce geometric estimates of asset depreciation, accords with actual market outcomes. Our econometric results are based on a rich database that contains detailed price and age information on over 25,000 individual assets.

New estimates aside, much of the value-added herein is, in our view, methodological. Our estimation framework differs significantly from earlier studies in that we model changes in asset value using estimation techniques that fall under the rubric of survival analysis. Our final results are based on a Weibull maximum likelihood survival model

that has been modified to produce estimates of depreciation. Our framework evaluates whether rates of depreciation are age-invariant (i.e., consistent with geometric accounting techniques) or variable at different stages of service life.

The structure of the chapter is as follows. Section 2.2 reviews a range of theoretical and empirical issues that motivate our study. Particular emphasis is placed on the use of constant-rate geometric estimates of economic depreciation that form the basis for perpetual inventory estimates of capital stock. We discuss the properties of our data sample in Section 2.3. We develop our econometric model in Section 2.4. Results are presented in Section 2.5. Estimates of capital stock based on a constrained (exponential) version of our Weibull depreciation model are evaluated in Section 2.6.

2.2 Theoretical Foundations

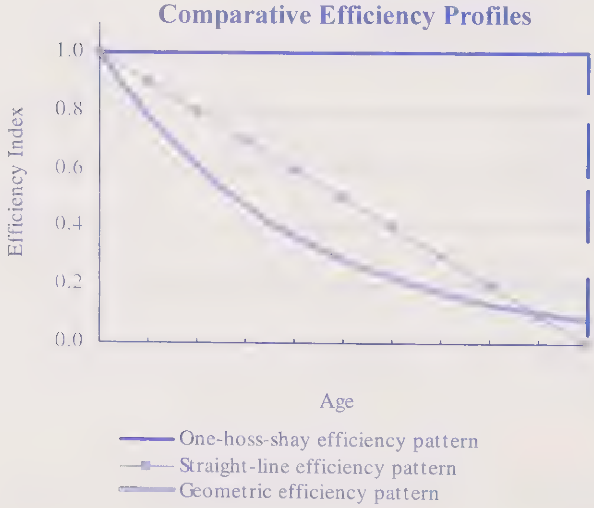
2.2.1 Efficiency and Depreciation

As economic concepts go, depreciation is ubiquitous. A central characteristic of any system of production, depreciation, in its most common usage, refers to how the elements of an economic system erode with age. When it is desirable to do so, economic agents respond to this decline in productive capacity by reinvesting—businesses, in replacement technologies or plants and equipment; governments, in infrastructure and other public goods. These examples invoke images of depreciation as an observable, physical process, one that describes the rate at which productive assets are ingested, and dictates the pace of offsetting investments in maintenance and replacement.

Given that popular notions of depreciation are often beset by the above imagery, precise working definitions need to be set out at the onset. In particular, care must be taken to distinguish *physical, or capacity*, depreciation from *economic depreciation*. The crucial distinction between these two types rests with *what* is eroding or decaying—the production capabilities of the asset itself, or its subsequent economic value.

To make this distinction, we start by focusing on the evolution of an asset's productive efficiency, that is, its ability to produce goods and services over the course of its service life. As the asset experiences wear and tear, its productive efficiency declines, and it undergoes a process of physical depreciation. One can envisage this process in a stylized framework by imagining a multi-period revenue stream that is directly proportional to the asset's productive capacity. We represent this process graphically using the set of efficiency profiles depicted in Figure 2.1.

Figure 2.1
Comparative Efficiency Profiles

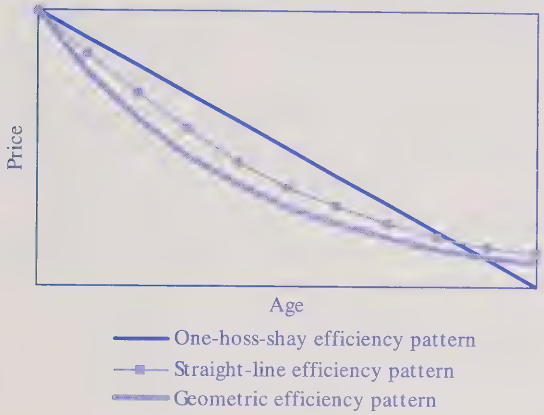


Following Hulten and Wykoff (1981), we consider three common efficiency profiles, beginning with the one-hoss-shay.[1] Assets with

[1] Much of this comes directly from Hulten and Wykoff (1981).

one-hoss-shay efficiency profiles undergo no physical depreciation over the course of their productive lifecycle. They retain their full ability to produce goods and services, and generate a constant stream of in-period revenue up until the end of their service life. Other assets may exhibit a straight-line efficiency profile, wherein their productive capacity, and in-period revenues, decline in progressive linear increments over their lifecycle. A final class of assets may exhibit geometric decay, yielding a convex-to-the-origin efficiency profile. This is an example of an accelerated pattern, in which declines in efficiency are more pronounced in earlier periods of service life than in later periods.

Figure 2.2
Corresponding Depreciation Profiles



We now turn to consider economic depreciation, defined as the decline in asset value (or asset price) associated with aging (Fraumeni, 1997). This price decline reflects, in the first instance, the reduction in present value that occurs over a finite service life. Other things equal, an older asset has less opportunity to generate revenue than a younger asset—which reduces the economic value of the former. This decline in asset value will be accelerated if aging is accompanied by a loss of productive efficiency, as all capital assets that suffer wear-and-tear can be expected to return a lower stream of benefits in any single period. In Figure 2.2, we examine the patterns of economic depreciation that correspond to the efficiency profiles presented in Figure 2.1.[2]

The decline in present value is most clearly seen in the one-hoss-shay case. In the simplest of worlds, one-hoss-shay efficiency profiles will give rise to linear depreciation patterns, as older assets, while still generating the same in-period revenue as their younger counterparts, are worth progressively less in each period.[3] This "general non equivalence" between asset efficiency and asset value is also apparent in the straight-line case. Linear efficiency profiles do not give rise to linear depreciation curves; rather, asset values follow a more accelerated pattern with higher losses in value earlier in service life. Geometric patterns represent the lone exception to this general nonequivalence—as one can here move interchangeably between a geometric "efficiency" framework and a geometric "value or price" framework with reductions in efficiency that mirror concomitant reductions in price.[4]

[2] Stylized relationships between asset efficiency and depreciation are generally predicated on two sufficient conditions—first, that service lives and efficiency patterns are known with certainty, and second, that an asset's price reflects the actualized value of its future stream of revenues where these revenues are a linear function of the capacity of the asset.

[3] We depict a linear depreciation profile here simply to illustrate the incremental decline in present value as the asset progresses through its service life. Note, however, that the depreciation curve corresponding to a one-hoss-shay efficiency profile will not be linear if (i) the duration of service life is not known with certainty, or (ii) the value of the asset's productive capacity is discounted in future periods. Hulten and Wykoff (1981) depict a concave-to-the-origin depreciation profile for assets with one-hoss-shay efficiency characteristics.

[4] Once again, this efficiency-price relationship is conditional on several factors; see note 2.

These heuristic examples are worth stressing in view of Hulten and Wykoff's (1981, p. 90) observation that relationships between efficiency and depreciation represent "the most misunderstood relationship in all of depreciation theory." The requirement that national accountants adopt a consistent treatment of efficiency and economic depreciation has been voiced, more recently, by Jorgenson (1994). At issue is the extent to which rates of economic depreciation can be adequately used to proxy rates of physical replacement when making perpetual inventory estimates of capital stock.

Our principal focus herein is with economic depreciation—the reduction in price or value associated with aging. Aging, however, is not equivalent to use, though we have tacitly treated it as such in the above examples. Asset values decline due to wear-and-tear and the reduction in present value as assets work their way through economic systems. Following Fraumeni (1997), changes in asset value are also driven by a continual process of "revaluation", that is, reductions in the value of older assets from period-to-period owing *inter alia* to increased obsolescence. There is an economic cost to holding older assets if new assets—assets that embody recent technological innovations—can lead to superior performance. Theoretical models of economic depreciation will often distinguish between the price effects of use and obsolescence, as it is not difficult to imagine circumstances in which the relative weight of the latter is a more significant determinant of overall price movements. Personal computers may undergo relatively little physical depreciation over their service life, and yet they may experience large declines in resale value due to the rapid onset of obsolescence.

Herein, we treat aging and obsolescence as basic determinants of the same process—in that both effect changes in the price of an asset over its lifecycle. This is consistent with the approach taken by statistical agencies when developing estimates of depreciation for systems of national accounts (Fraumeni, 1997).

2.2.2 Straight-line and Geometric Forms

In this section, we draw attention to two specific forms of depreciation: straight-line and geometric. While much of our analytical interest rests with the latter, straight-line depreciation is a useful starting point, and is applied extensively in a national accounting framework.

The simple algebra of straight-line and geometric depreciation is outlined by Fraumeni (1997). We present much of her discussion below.

Straight-line patterns assumes equal dollar value depreciation at all stages of an asset's lifecycle. Per-period depreciation for a dollar of investment takes the form

$$D = \frac{1}{L} \tag{1}$$

where L is service life. Although the dollar loss is equal from period-to-period, the rate of depreciation—that is, the percent change in asset value from period-to-period—increases progressively over the course of an asset's service life. For a marginal dollar of investment, this rate is

$$\delta_i = \frac{1}{L-(i-1)}, \text{ for all periods } i=1,\ldots,L. \tag{2}$$

Geometric depreciation represents the conceptual counterpoint to the straight line case. Geometric profiles hold the *rate* of depreciation, not the period-to-period dollar amount, fixed over the course of an asset's service life. Geometric profiles are accelerated—with higher dollar depreciation in early periods—giving rise to the convex age-price profile depicted in Figure 2.2. Per-period depreciation is defined as

$$D_i = \delta(1-\delta)^{(i-1)} \tag{3}$$

where δ is the constant (age invariant) rate of depreciation.

The majority of empirical research on asset depreciation has concentrated on the geometric form. In early studies, geometric patterns were often assumed. Evidence that geometric rates are generally appropriate for a wide range of asset types is found in Hulten and Wykoff (1981) and Koumanakos and Hwang (1988).[5] In practice, geometric rates are analytically expedient in two important respects: (1) they can be estimated indirectly via accounting methods; and (2) their constant-rate property allows them to be used as a proxy for the replacement rate in standard perpetual inventory models of capital stock. We address the first of these points below.

Direct estimates of δ generally require information on resale prices. In the absence of sufficient price information, geometric rates can be calculated indirectly as

$$\delta = \frac{DBR}{L} \tag{4}$$

where DBR is a (constant) declining-balance rate and L is service life. The value of the declining balance rate determines, other things equal, the extent to which asset values erode more rapidly early in the lifecycle (Fraumeni, 1997). Higher values of the declining balance rate bring about higher reductions in asset value earlier in service life, giving rise to more convex (i.e., accelerated) depreciation profiles.[6] The indirect rate of depreciation produced by equation 4 is *ex ante* in the sense that the value of the DBR is set to some fixed constant *a priori,* and because the estimates of L are generally based on *ex ante* expectations of service life. Estimates of L have traditionally come from experts in the field or from tax codes. In Canada, service life estimates have been derived from the expectations of survey respondents regarding an asset's useful life.

[5] For a survey of the empirical literature, see Fraumeni (1997); for a discussion of empirical methods, see Jorgenson (1994).

[6] The concept of a finite service life, however, is not particularly well suited to the geometric case. To see this, note that service life L is not finite, in the same sense that it can be considered finite in the straight-line case. Straight-line patterns depreciate at a constant dollar amount until the economic value of an asset is exhausted, that is, up until the point of retirement. In contrast, the geometric patterns given by equations 3 and 4 are infinite in that some (progressively declining) portion of asset value continues to survive *after* service life L. This "surplus" or remaining asset value is not necessarily trivial. Consider a hypothetical asset which has a mean service life of 25 years. If we base our estimates of geometric depreciation on the double-declining balance rate (DBR=2), 13.5% of asset value survives beyond the mean retirement age. This "infinite" characteristic of geometric forms has occasioned the use of truncation techniques which adjust depreciation estimates upwards in order to exhaust total asset value at service life L.

There has been considerable debate over whether the assumptions embodied in the calculation of geometric rates are empirically appropriate. Some researchers have questioned whether the heavy losses in asset value that are often observed early in asset life are consistent with constant, geometric rates. It should be stressed that constant rates do not, in and of themselves, preclude highly accelerated depreciation profiles; rather, the issue is simply whether these rates are, on net, sensible representations of the change in asset value in *every* period. A key aspect of this debate centers on defining an appropriate value for the declining balance rate. Even if constant-rate, geometric age-price profiles are empirically justified, the choice of particular values for *DBR* and *L* is still at issue. Much concern rests with the presumed *ad hoc* nature of the declining-balance rate *DBR*. While estimates of service life *L* often derive from expert sources, assumptions about the declining-balance rate are, at first blush, less transparent.

Double-declining balance rates (*DDBR*)—which set the value of the *DBR* equal to 2—have been extensively used in practice. In their estimates of capital stock, Christensen and Jorgenson (1969) employ double-declining balance rates to estimate rates of economic depreciation. Statistics Canada's productivity program has historically based its estimates of geometric depreciation on a double-declining rate. One advantage of the *DDBR* is that it provides a "conceptual bridge" back to the straight-line case, anchoring the midpoints of these depreciation schedules at an equivalent age point. To see this, we can examine a simple measure of central tendency. Using the *DDBR*, the midpoint of the geometric curve is

$$\mu = \frac{1}{\delta}\text{, or equivalently from equation 4,} \tag{5}$$

$$\mu = \frac{L}{DBR} = \frac{L}{2} \tag{6}$$

while $\frac{L}{2}$ also represents the midpoint of the depreciation schedule in the straight line case.[7] Recent estimates of geometric depreciation used by the U.S. Bureau of Economic Analysis assume a lower value for the declining balance rate for many individual assets (*DBR*=1.65 for machinery and equipment and 0.91 for structures). Based on the empirical research of Hulten and Wykoff (1981), these values will, other things equal, produce lower rates of geometric depreciation than the double-declining case.

The basis for the Hulten-Wykoff estimates of the *DBR* warrant some discussion here. In a study for the Office of Tax Analysis of the U.S. Department of the Treasury, the authors generate direct estimates of geometric depreciation for a large variety of assets based on samples of used-asset prices, and then base subsequent estimates of δ (for assets for which no price information was available) on the geometric accounting method described by equation 4. This two-stage procedure enabled the authors to produce a set of depreciation estimates that was consistent with the asset classes used by the U.S. National Income and Product Accounts. To produce geometric rates of depreciation from equation 4, Hulten and Wykoff calculated average values for the declining balance rate *DBR* using their price-based estimates of δ and exogenous information on service life. This yielded average *DBR* values of 1.65 for machinery and equipment and

[7] For an overview of the geometric distribution, see Hastings and Peacock (1975).

0.91 for structures—average *DBR* values based on asset categories for which price information was directly available.[8] In cases where no price information was available, the authors then combined these estimates of *DBR* with asset-specific information on service life *L* to produce indirect estimates of δ.[9]

One advantage of our study is that we can ask whether *ex ante* depreciation rates that derive from a geometric accounting framework are consistent with the *ex post* rates produced by our econometric models. We examine this in Section 2.5 by asking whether summary measures of asset life from our econometric estimates of depreciation (which derive from price information collected over an 11 year period) are consistent with recent survey evidence on asset life which can be used to estimate δ via equation 4.

2.3 Data Source

The data used for this study come from Statistics Canada's annual *Capital and Repair Expenditures Survey*, an establishment-based survey in which respondents are asked to report on their sales and disposals of fixed assets. Respondents to the survey operate in a broad mix of goods and services industries. The survey provides detailed information on asset type, gross book value, sale price, and age. Our data set was constructed by merging a series of cross-sectional survey frames, creating a database on used-asset prices that covered an 11 year reporting period (1985-1996).

The sample used for our analysis was generated in several stages. Our initial base sample had 53,802 observations on 240 separate assets. Many of these observations, however, could not be used due to data limitations. We first removed observations that were missing information on age and/or initial book value. These observations comprised 43% of the initial base sample. We then excluded institutional assets from our sample (e.g., schools, hospitals, universities). This reduced our dataset to 30,235 observations on 119 assets. To ensure that our econometric estimates are robust, we restricted our analysis to individual assets with more than 100 observations. This further reduced our sample of usable observations to 28,089 observations on 33 assets.

A final stage of our editing strategy was to review the sample for outliers. To ensure consistency across asset types, we adopted systematic rules for outlier identification. We describe our technique for identifying and eliminating outliers in Appendix 2.A. Our final analysis file contains over 25,000 usable observations on 33 individual assets, covering two asset classes: structures and machinery and equipment. We review the characteristics of the final sample in Table 2.1.

Studies that use market prices to estimate depreciation profiles must address issues of data reliability.[10] Traditionally, used-asset samples have not contained information on retirements, which, in turn, biases the estimation of depreciation profiles. In their 1981 study, Hulten and Wykoff controlled for retirements by weighting their price data by survival probabilities. Methodological adjustments of this sort are not required herein, as information on discards is included directly in our database.

[8] As Hulten and Wykoff (1981) note, the asset categories for which they were able to calculate depreciation rates directly from price information represent a substantial share of total NIPA investment expenditures—42% of investment in non-residential structures and 55% of investment in producers' durable equipment.

[9] For a useful discussion of the Hulten-Wykoff methodology, see Fraumeni (1997).

[10] Once again, for a general discussion of these issues, see Fraumeni (1997).

Table 2.1 Data Sample

Asset Code	Number of Observations	Description
1001	791	Plants for Manufacturing
1006	268	Warehouses, Refrigerated Storage, Freight Terminals
1008	151	Maintenance Garages, Workshops, Equipment Storage Facilities
1013	626	Office Buildings
1016	202	Shopping Centers, Plazas, Malls, Stores
1099	168	Other Industrial and Commercial
3002	162	Telephone and Cablevision Lines, Underground and Marine Cables
3003	128	Communication Towers, Antennae, Earth Stations
6001	2,651	Office Furniture, Furnishings (e.g., desks, chairs)
6002	2,484	Computers, Associated Hardware and Word Processors
6003	875	Non-Office Furniture, Furnishings and Fixtures (e.g. recreational equipment, etc.)
6004	871	Scientific, Professional and Medical Devices
6005	365	Heating, Electrical, Plumbing, Air Conditioning and Refrigeration Equipment
6006	124	Pollution Abatement and Control Equipment
6007	118	Safety and Security Equipment (including firearms)
6009	571	Motors, Generators, Transformers, Turbines, Compressors and Pumps of all types
6010	596	Heavy Construction Equipment (e.g., loading, hauling, mixing, paving, grating)
6011	459	Tractors and Other Field Equipment (truck tractors - see 6203)
6012	707	Capitalized Tooling and Other Tools (hand, power, industrial)
6013	127	Drilling and Blasting Equipment
6201	2,554	Automobiles and Major Replacement Parts
6202	204	Buses (all types) and Major Replacement Parts
6203	3,086	Trucks, Vans, Truck Tractors, Truck Trailers and Major Replacement Parts
6205	207	Locomotives, Rolling Stock, Street and Subway Cars, Other Rapid Transit and Major Parts
6206	104	Ships and Boats and Major Replacement Parts
6207	223	Aircraft, Helicopters, Aircraft Engines and Other Major Replacement Parts
6299	209	Other Transportation Equipment
6402	539	Computer-assisted Process for Production Process
6403	267	Computer-assisted Process for Communication and Related Equipment
6601	1,001	Non-computer Assisted Process for Material Handling
6602	2,918	Non-computer Assisted Process for Production Process
6603	595	Non-computer Assisted Process for Communication and Related Equipment
8999	745	Other Machinery and Equipment (not specified elsewhere)

A second concern with used-asset prices rests with Ackerlof's (1970) "lemon's hypothesis". According to this view, assets sold in resale markets are inferior to those that owners retain for production. In practice, variants of the lemons hypothesis are all predicated on the existence of information asymmetries between buyers and sellers. The extent to which lemons issues limit the utility of used-asset studies is dependent *inter alia* upon one's preconceptions about the ability of markets to solve information problems. For instance, the emergence of market intermediaries that provide used-asset information to prospective buyers will reduce the severity of these information asymmetries. In addition, the existence of different market segments, corresponding to different quality types, also reduces the impact of lemons problems. Herein, we align ourselves with the orthodox position—and take the view that used-asset prices can tell us much about economic depreciation. We should stress that our edit strategy eliminates some of the more apparent lemons—observations with extremely low resale values, relative to like assets, early in service life.

Finally, concerns over representativeness often come to the fore when results are based on small samples. Hulten and Wykoff (1981) and Koumanakos and Hwang (1988) notwithstanding, much of empirical work on asset depreciation has been based on small samples for limited numbers of assets. Herein, our database confers certain advantages, as we were able to amass a large and diverse set of price information based on a comprehensive annual investment survey taken by Canada's national statistical agency.

2.4. Estimation Framework

2.4.1 Survival Ratios and Weibull Distributions

As Jorgenson (1994, p. 1) observes, "the challenge facing economic statisticians" engaged in research on economic depreciation "is to employ asset-price information effectively." Econometric studies that use vintage prices to estimate depreciation curves build on the pioneering work of Hall (1971) and Hulten and Wykoff (1981). Hall introduced an analysis of variance model in which prices were estimated as a function of age- and time-specific dummies. A major contribution of Hall's model is the estimation of nonlinear time and age effects.[11] Hulten and Wykoff extended econometric (and nonlinear) research on depreciation schedules by utilizing a Box-Cox model which tests for the appropriateness of various functional forms (rectangular, straight-line, and geometric). Koumanakos and Hwang (1988) applied this Box-Cox approach to their analysis of Canadian assets using 1987 data on used-asset prices.

Our estimation approach differs from earlier research on asset depreciation in that we model changes in asset value using survival analysis methods. Our basic unit is a survival ratio, observed at some age *t*. For all observations i in our sample, we calculate this *survival ratio* as

$$R_i = \frac{SP_i}{GBV_i} \tag{7}$$

where *SP* is the selling or discard price of the asset at age *t*, and *GBV* is its gross book value. Both numerator and denominator are expressed in constant dollars with the selling price *SP* deflated in the survey year, and *GBV* in the asset's initial year of its service life. R_i is thus the share of asset value that remains when the asset is sold at some reported age *t*. If the asset has been retired without a sale, R_i equals 0, corresponding to a zero selling price.

Our estimation model posits that changes in asset value can be modeled using a Weibull distribution. A two-parameter distribution, survivor and hazard functions for the Weibull are defined as

$$S(t) = \exp[-(\lambda t)^{\rho}], \text{ and} \tag{8}$$

$$h(t) = \lambda\rho(\lambda t)^{\rho-1} \tag{9}$$

where ($\lambda > 0$) and ($\rho > 0$).

Extensively used in duration analysis, the Weibull distribution is a flexible parametric form that can be readily integrated into a depreciation framework. Weibull formulations allow for variable, age-variant rates of depreciation, but can be restricted to produce constant (exponential) rates that are directly comparable to the geometric rates

[11] A more thorough review of the empirical work noted here—particularly Hall (1971) and Hulten and Wykoff (1981)—is found in Jorgenson (1994). Our discussion here is by no means exhaustive. For a more comprehensive review, see Jorgenson (1994) and Fraumeni (1997).

commonly used in depreciation accounting. Accordingly, then, we can place our estimation framework, for comparative purposes, squarely within the geometric orthodoxy.

In what follows, we develop three different econometric specifications for our Weibull survival model.

2.4.2 OLS Average-price Weibull Model

We begin the development of our estimation framework by introducing a simple linear version of our survival model. This represents, in effect, a base specification that we use strictly for comparative purposes.

Taking the natural logarithm of the Weibull survivor function (equation 8) and multiplying by (-1) yields:

$$-\log(S) = (\lambda t)^{\rho} . \tag{10}$$

Transforming this into linear form, we have

$$\log[-\log(S)] = \rho[\log \lambda + \log t] . \tag{11}$$

Accordingly, an OLS regression of the form

$$y = a + bx + u \tag{12}$$

will yield estimates of the Weibull parameters where

$$\lambda = \exp(a / \rho) \text{ and} \tag{13}$$

$$\rho = b .^{12} \tag{14}$$

In standard survival analysis models, the estimation of equation 12 is often based on nonparametric estimates of the survivor function, which derive from empirical estimates of the hazard rate (the ratio of events to the total population at risk at each age t). Kaplan-Meier survivor function estimates are commonly used for this purpose.[13]

Our estimation framework differs from standard survival applications in that we are interested in modelling changes in asset value, as opposed to the existence of the asset itself.[14] Changes in valuation (i.e., depreciation) occur incrementally over all stages of service life, as opposed to instantaneously at some age t. In this sense, the individual survival ratios in our asset samples R_i depict a concept of cumulative loss, rather than some instantaneous, or discrete, reduction in asset value. Consequently, these individual price ratios are not, in strict conceptual terms, consistent with the type of events that generate an empirical hazard—all of which occur discretely at some age . For this reason, we estimate equation 12 using a weighted average-price calculated independently

[12] For a useful discussion, see Lawless (1982).

[13] For background on this technique, see Kiefer (1988).

[14] We address the issue in much greater detail when developing our maximum-likelihood survival model in Section 2.4.3.

at each point in an asset's age distribution. Taken together, these average prices trace out the coordinates of an aggregate age-price profile. This weighted average is

$$\bar{R}(t) = \frac{\sum SP_i}{\sum GBV_i} \quad (15)$$

The dependent variable in our linear model is obtained by substituting the above average price expression (equation 15), effectively an average survival ratio, for the term on the left-hand side of equation 11. The right-hand side variable in equation 11 is just log age. Once the OLS parameters have been transformed into Weibull parameters (equations 13 and 14), the depreciation profile is generated by plotting solution values for the survivor function (equation 8). This depreciation curve is a locus of probability estimates, giving the share of asset value that survives beyond each age t.

We can generate an exponential (constant-rate) variant of this model simply by restricting the value of the Weibull parameter ρ. When ρ equals unity, the rate of depreciation occurs at a constant rate—defined by the exponential hazard rate λ. This rate represents the linkage between our survival framework and the geometric accounting methods described by equation 4, as the exponential distribution is simply the continuous-time version of the geometric. To see this, note that geometric depreciation can be expressed as $\left(1-\frac{\lambda}{m}\right)^{mt}$ where t represents age, λ is the rate of depreciation and m, the frequency at which this rate is extracted from the original value within the period (this is equivalent to the compounding period). This geometric distribution tends to the exponential when the compounding frequency becomes instantaneous. That is,

$$\lim_{m\to\infty}\left(1-\frac{\lambda}{m}\right)^{mt} = e^{-\lambda t}. \quad (16)$$

[15]

It is worth stressing that, issues of conceptual appropriateness aside, the estimation of equation 11 via full samples of individual prices is problematic. Large numbers of observations in our asset samples are discards—observations with a 0 value for R_i due to a reported 0 selling price. Since the transformation from equation 8 to equation 11 requires positive prices, zero prices would have to be replaced by some nominal, positive decimal value. But the subsequent LS estimates would be biased due to density accumulation on this point. In a (naturally) linear model, Tobit-style adjustments can be made to remove this bias.[16] However, in our case, the linear estimation model has been transformed, rendering the point of density accumulation undefined.

The estimation of equation 11 via weighted average-prices entails significant losses of sample information. The case of computers is illustrative. A relatively short-lived asset, price information exists for only 17 years. Accordingly, depreciation estimates from the linear average-price model are based on summary price information described by 17 sample points. Yet, as reported in Table 2.1, almost 2,500 individual observations exist

[15] For discussion, see Silberberg (1990).
[16] See Greene (1981).

for computers. In what follows, we develop a micro-estimation framework that generates depreciation profiles from this and other asset samples directly.

2.4.3 Maximum-likelihood Survival Model

We begin by considering asset valuation within the standard maximum-likelihood framework.

Let y define a dummy variable describing the two possible life states for a given asset, and let

y=1 when the asset is dead or retired (its sale value equals zero)

y=0 if otherwise.

The likelihood of an observation $l(t)$ is

$$l(t) = f(t)^{y} S(t)^{(1-y)} \tag{17}$$

where $f(t)$ is the density function, and $S(t)$ the survival function.[17]

Equation 17 is best applied to situations in which the event being modelled can be described using binary life states (e.g., "completely" alive or "completely" dead). If the asset is "dead", the likelihood function reduces to the density function, and gives the probability of death at age t. If the asset is still "alive", the likelihood reduces to the survival function, and gives the probability that it survives until t. The log-likelihood of observing a sample of n observations then takes the form

$$\ln L = \sum_{i=1}^{n} \left[y_i \ln f(t_i) + (1 - y_i) \ln S(t_i) \right]. \tag{18}$$

We now modify equation 18 based on our set of observed survival ratios R_i (defined previously by equation 7) which describe the extent to which the asset is alive or dead. These price ratios are continuous, not binary, and can take on any value in the open set (0,1). Accordingly, each observation in the sample simultaneously represents two pieces of information: R_i, the portion of asset value that survives at some age t, and $1 - R_i$, the portion of asset value lost at t. The log-likelihood of a sample of n observations becomes

$$\ln L = \sum_{i=1}^{n} \left[(1 - R_i) \ln f(t_i) + R_i \ln S(t_i) \right]. \tag{19}$$

[17] This is consistent with the standard model of survival. See for example, Cox and Oakes (1984) and Wayne (1982).

The log likelihood formulation given by equation 19 has an intuitive interpretation. R_i, the price ratio, represents the amount of asset value that survives to some age t, multiplied by a corresponding survival probability $S(t_i)$, while $1-R_i$ represents the amount of value lost, multiplied by its failure probability $f(t_i)$.

While well suited to many survival applications, equation 19 needs to be modified in order to produce estimates of economic depreciation. The issue rests with the use of the standard density formulation $f(t_i)$ as a sensible probability concept when modelling the (continuous) loss of asset value. By specifying a density term, the above equation assumes that asset values remain unchanged in all periods prior to the point of transaction, that is, prior to being sold or retired. Embedded, then, in equation 19 are depreciation profiles that are conceptually similar to a "one-hoss-shay"—with asset values remaining at their maximum survival ratio prior to some age period (the point of transaction t) at which some partial or total loss in value is observed.

We can modify equation 19 to adjust for continuous depreciation by replacing the density term $f(t_i)$ with the cumulative density $F(t_i)$. While the density term $f(t_i)$ assumes that the loss in asset value occurs at t, the cumulative density $F(t_i)$ assumes that reductions in value occur *before* time t.

Our estimation equation becomes

$$\ln L = \sum_{i=1}^{n} \left[(1-R_i)\ln F(t_i) + R_i \ln S(t_i)\right] \tag{20}$$

where $F(t_i)$ is the probability that asset values will decline at some point prior to t.[18] To estimate the above model using the Weibull distribution, we express the cumulative density $F(t_i)$ and survivor function $S(t_i)$ as

$$S(t) = \exp[-(\lambda t)^{\rho}] \tag{21}$$

$$F(t) = 1 - \exp[-(\lambda t)^{\rho}]. \tag{22}$$

Once again, restricting the parameter ρ will produce the exponential or continuous-time geometric version of the model with the survivor and cumulative density functions

$$S(t) = \exp(-\lambda t) \tag{23}$$

[18] This is similar to binary response models where the level of response (time) is observation specific. Our formulation resembles one of the prototypes listed by Lagakos (1979)—in which observations share a common survival distribution, but different censoring experiences. In our framework, the likelihood function is both left- and right-censored, and the usual indicator variable y is replaced by a survival ratio R_i.

$$F(t) = 1 - \exp(-\lambda t). \tag{24}$$

Estimation of equation 20 based on individual survival ratios R_i assumes that depreciation schedules are not correlated with the size—or dollar value—of the asset. To account for dollar value differences across observations, we weight each observation by its share of total asset value, multiplied by the number of observations in the asset sample.[19] Denoting this weight as w_i, we can rewrite equation 20 as

$$\ln L = \sum_{i=1}^{n} w_i \left[(1 - R_i)\ln F(t_i) + R_i \ln S(t_i)\right]. \tag{25}$$

2.4.4 Adjusting our Depreciation Model to Allow for Patterns of Digit Preference

For many of the asset samples, survey respondents exhibited patterns of digit preference. This is evidenced by relatively high numbers of observations clustered at five-year intervals. These patterns of age-rounding can affect the estimation of our model. Accordingly, we derive an alternative version of our ML survival model (equation 25) that takes digit preference into account.

If age-rounding is apparent, the true age of the asset t^* at the time of transaction (sale or discard) is observed with some rounding error. If we assume that t^* falls within some upper and lower age bound, we can express the likelihood function as

$$\ln L = \sum_{i=1}^{n} w_i \left[(1 - R_i)\ln F(UB) + R_i \ln S(LB)\right]. \tag{26}$$

Equation 26 requires some explanation. Although the portion of the likelihood function that defines the loss in asset value cannot be measured with certainty at age t^*, it is sensible to assume that this decline occurs prior to some unknown upper bound age UB (where $UB > t^*$). Conversely, for the portion of the likelihood function that corresponds to survival, we assume that asset value survives beyond some unknown lower bound age LB (where $LB < t^*$).

We can operationalize these concepts using a series of (0,1) dummy variables that correspond to discrete points in the age distribution where rounding is likely to occur. Let δ be a dummy variable which takes a value of 1 when there is a rounding problem, 0 if otherwise. Let $\sigma_5, \sigma_{10}, \sigma_{15}, \sigma_{20}$ represent the presence of this problem respectively at ages 5, 10, 15 and 20. This results in four intervals, each with a lower and an upper bound, with eight corresponding parameters. We can simply this framework for the purpose of estimation. First, we assume that there is no systematic rounding error. This enables us to center the intervals on the rounded values—which reduces the number of estimated parameters from 8 to 4. Second, we assume that adjacent bounds are equal

[19] Accordingly, the sum of the weights is equal to the total number of observations. No artificial degrees of freedom are created.

between interval spaces.[20] If there are 3 adjacent areas, this reduces the number of required parameters from 4 to 1.[21]

The log-likelihood of a sample of n observations adjusting for patterns of digit preference becomes

$$\ln L = \sum_{i}^{n} w_i \left[\begin{array}{l} (1-\delta)_i \left[(1-R_i)\ln F(t_i) + R_i \ln S(t_i) \right] + \\ \delta_i \left[\sum_{r=5,10,15,20}^{20} \sigma_r \left((1-R_i)\ln\left(F(UB_r)\right) + R_i \ln(S(LB_r)) \right) \right] \end{array} \right] \tag{27}$$

where $F(t_i)$ and $S(t_i)$ represent the Weibull cumulative density and survival functions.[22]

We now have three variants of our Weibull survival model: the OLS average-price model (equation 11), the ML survival model without corrections for digit preference (equation 25) and the ML survival model with corrections for digit preference (equation 27).

2.5 Empirical Results

2.5.1 Comparative Survival Models

In tables 2.2 and 2.3, we report depreciation profiles for assets in our sample based on each of the three econometric methods outlined above. Each depreciation profile is represented as a locus of survivor function estimates (SFEs) corresponding to different stages of the asset's lifecycle. Accordingly, individual SFEs represent the portion of total asset value that survives beyond *t*. For individual assets in the structures class, we report SFEs for the first five years of life, and then at discrete 5 year intervals, covering ages 10 through 25. Our objective here is to examine depreciation profiles at both early and late stages of the lifecycle, in light of *a priori* expectations that assets in the structures class are more likely to exhibit relatively long service lives. For assets in the machinery and equipment class, we report SFEs continuously over the first ten years of service life.

Results in tables 2.2 and 2.3 are either unrestricted Weibull estimates (denoted as "W" in column 2) or restricted-Weibull, exponential estimates (denoted as "E")—depending upon which constitutes the optimal specification. In cases where the null of a constant, age-invariant (exponential) rate of depreciation was rejected, Weibull estimates are reported. In cases where the null could not be rejected, the restricted exponential (or continuous-time geometric) estimates are reported.

Our use of different estimation techniques (represented by equations 11, 25, 27) allows us to gauge the extent to which depreciation profiles are sensitive to different operational versions of our survival model. As discussed in Section 2.4, the average-price

[20] This is consistent with the ordered response model. Equal interval space requires that the lower bound of an upper interval is equal to the upper bound of the interval directly below it.

[21] Functionally, we refer to this as the *MRE*—the magnitude of rounding error at age 5 and 15. LB_5, LB_{10}, LB_{15} and LB_{20}, the lower bounds of the intervals, can be defined as *5-MRE, 5+MRE, 15-MRE, 15+MRE* while UB_5, UB_{10}, UB_{15} and UB_{20}, the upper bounds, are *5+MRE, 15-MRE, 15+MRE* and *25-MRE*.

[22] Tests for specification and heterogeneity are discussed in Appendix 2.B.

Table 2.2 Ratio of the Residual Value: Machinery and Equipment

		Age of Assets									
Asset	Model	1yr	2yr	3yr	4yr	5yr	6yr	7yr	8yr	9yr	10yr
Office Furniture, Furnishings (6001)											
MLS (Eq. 27)	W	0.79	0.59	0.43	0.31	0.22	0.16	0.11	0.08	0.05	0.04
MLS (Eq. 25)	W	0.64	0.45	0.33	0.24	0.18	0.14	0.11	0.08	0.06	0.05
OLS (Eq. 11)	W	0.88	0.73	0.59	0.47	0.37	0.29	0.22	0.17	0.13	0.09
Computers, Associated Hardware and Word Processors (6002)											
MLS (Eq. 27)	W	0.56	0.31	0.18	0.10	0.06	0.03	0.02	0.01	0.01	0.00
MLS (Eq. 25)	E	0.56	0.32	0.18	0.10	0.06	0.03	0.02	0.01	0.01	0.00
OLS (Eq. 11)	E	0.67	0.45	0.30	0.20	0.14	0.09	0.06	0.04	0.03	0.02
Non-office Furniture, Furnishings and Fixtures (6003)											
MLS (Eq. 27)	W	0.89	0.75	0.61	0.49	0.38	0.29	0.22	0.17	0.12	0.09
MLS (Eq. 25)	E	0.80	0.64	0.51	0.41	0.33	0.26	0.21	0.17	0.13	0.11
OLS (Eq. 11)	E	0.81	0.66	0.54	0.44	0.36	0.29	0.23	0.19	0.16	0.13
Scientific, Professional and Medical Devices (6004)											
MLS (Eq. 27)	W	0.88	0.71	0.55	0.41	0.29	0.21	0.14	0.09	0.06	0.04
MLS (Eq. 25)	E	0.72	0.53	0.38	0.28	0.20	0.15	0.11	0.08	0.06	0.04
OLS (Eq. 11)	W	0.91	0.78	0.66	0.54	0.43	0.35	0.27	0.21	0.16	0.12
Heating, Electrical, Plumbing, Air Conditioning and Refrigeration Equipment (6005)											
MLS (Eq. 27)	E	0.77	0.59	0.45	0.34	0.26	0.20	0.15	0.12	0.09	0.07
MLS (Eq. 25)	E	0.74	0.54	0.40	0.29	0.22	0.16	0.12	0.09	0.06	0.05
OLS (Eq. 11)	W	0.89	0.75	0.60	0.46	0.35	0.26	0.19	0.13	0.09	0.06
Pollution Abatement and Control Equipment (6006)											
MLS (Eq. 27)	E	0.80	0.64	0.51	0.41	0.33	0.26	0.21	0.17	0.13	0.11
MLS (Eq. 25)	E	0.78	0.61	0.48	0.37	0.29	0.23	0.18	0.14	0.11	0.08
OLS (Eq. 11)	E	0.59	0.35	0.21	0.12	0.07	0.04	0.03	0.02	0.01	0.01
Safety and Security Equipment (6007)											
MLS (Eq. 27)	E	0.64	0.41	0.26	0.17	0.11	0.07	0.04	0.03	0.02	0.01
MLS (Eq. 25)	E	0.58	0.34	0.20	0.12	0.07	0.04	0.02	0.01	0.01	0.00
OLS (Eq. 11)	E	0.58	0.33	0.19	0.11	0.06	0.04	0.02	0.01	0.01	0.00
Motors, Generators, Transformers, Turbines, Compressors and Pumps of all types (6009)											
MLS (Eq. 27)	W	0.63	0.48	0.38	0.31	0.25	0.21	0.18	0.15	0.13	0.11
MLS (Eq. 25)	W	0.45	0.33	0.26	0.21	0.17	0.15	0.13	0.11	0.10	0.08
OLS (Eq. 11)	W	0.94	0.86	0.77	0.68	0.59	0.50	0.43	0.36	0.30	0.25

Table 2.2 Ratio of the Residual Value: Machinery and Equipment *Continued*

Asset	Model	Age of Assets 1yr	2yr	3yr	4yr	5yr	6yr	7yr	8yr	9yr	10yr
Heavy Construction Equipment (6010)											
MLS (Eq. 27)	E	0.83	0.68	0.56	0.46	0.38	0.32	0.26	0.22	0.18	0.15
MLS (Eq. 25)	E	0.82	0.68	0.55	0.46	0.37	0.31	0.25	0.21	0.17	0.14
OLS (Eq. 11)	W	0.90	0.78	0.66	0.55	0.45	0.36	0.29	0.23	0.18	0.14
Tractors and Other Field Equipment (6011)											
MLS (Eq. 27)	E	0.82	0.68	0.56	0.46	0.38	0.31	0.26	0.21	0.18	0.15
MLS (Eq. 25)	E	0.83	0.69	0.58	0.48	0.40	0.33	0.28	0.23	0.19	0.16
OLS (Eq. 11)	E	0.83	0.69	0.57	0.47	0.39	0.32	0.27	0.22	0.18	0.15
Capitalized Tooling and Other Tools (6012)											
MLS (Eq. 27)	E	0.61	0.37	0.22	0.13	0.08	0.05	0.03	0.02	0.01	0.01
MLS (Eq. 25)	E	0.61	0.38	0.23	0.14	0.09	0.05	0.03	0.02	0.01	0.01
OLS (Eq. 11)	E	0.80	0.63	0.50	0.40	0.32	0.25	0.20	0.16	0.13	0.10
Drilling and Blasting Equipment (6013)											
MLS (Eq. 27)	E	0.80	0.65	0.52	0.42	0.34	0.27	0.22	0.17	0.14	0.11
MLS (Eq. 25)	E	0.81	0.66	0.54	0.44	0.35	0.29	0.23	0.19	0.15	0.13
OLS (Eq. 11)	W	0.93	0.81	0.68	0.56	0.44	0.34	0.26	0.19	0.14	0.10
Automobiles and Major Replacement Parts (6201)											
MLS (Eq. 27)	E	0.79	0.62	0.49	0.38	0.30	0.24	0.19	0.15	0.12	0.09
MLS (Eq. 25)	E	0.79	0.62	0.49	0.39	0.30	0.24	0.19	0.15	0.12	0.09
OLS (Eq. 11)	E	0.77	0.59	0.45	0.34	0.26	0.20	0.15	0.12	0.09	0.07
Buses (all types) and Other Field Equipment (6202)											
MLS (Eq. 27)	E	0.82	0.67	0.55	0.45	0.37	0.30	0.25	0.20	0.17	0.14
MLS (Eq. 25)	E	0.82	0.68	0.56	0.46	0.37	0.31	0.25	0.21	0.17	0.14
OLS (Eq. 11)	W	0.47	0.34	0.26	0.20	0.17	0.14	0.12	0.10	0.09	0.07
Trucks, Vans, Truck Tractors, Truck Trailers and Major Replacement Parts (6203)											
MLS (Eq. 27)	E	0.79	0.62	0.49	0.38	0.30	0.24	0.19	0.15	0.12	0.09
MLS (Eq. 25)	W	0.62	0.47	0.38	0.31	0.25	0.21	0.18	0.15	0.13	0.12
OLS (Eq. 11)	E	0.82	0.67	0.55	0.45	0.37	0.30	0.25	0.21	0.17	0.14
Locomotives, Rolling Stock, Street and Subway Cars, Other Rapid Transit and Major Parts (6205)											
MLS (Eq. 27)	E	0.85	0.72	0.61	0.52	0.44	0.38	0.32	0.27	0.23	0.20
MLS (Eq. 25)	E	0.85	0.72	0.61	0.52	0.44	0.37	0.31	0.27	0.23	0.19
OLS (Eq. 11)	E	0.81	0.65	0.53	0.43	0.35	0.28	0.23	0.18	0.15	0.12

Table 2.2 Ratio of the Residual Value: Machinery and Equipment – *Concluded*

		Age of Assets									
Asset	Model	1yr	2yr	3yr	4yr	5yr	6yr	7yr	8yr	9yr	10yr
Ships and Boats and Major Replacement Parts (6206)											
MLS (Eq. 27)	E	0.90	0.80	0.72	0.64	0.58	0.52	0.46	0.42	0.37	0.33
MLS (Eq. 25)	E	0.90	0.80	0.72	0.64	0.58	0.52	0.46	0.41	0.37	0.33
OLS (Eq. 11)	E	0.87	0.76	0.67	0.58	0.51	0.44	0.39	0.34	0.29	0.26
Aircraft, Helicopters, Aircraft Engines and Other Major Replacement Parts (6207)											
MLS (Eq. 27)	W	1.00	1.00	0.99	0.97	0.95	0.93	0.90	0.86	0.81	0.76
MLS (Eq. 25)	E	0.95	0.89	0.84	0.80	0.75	0.71	0.67	0.64	0.60	0.57
OLS (Eq. 11)	E	0.92	0.85	0.79	0.73	0.67	0.62	0.58	0.53	0.49	0.46
Other Transportation Equipment (6299)											
MLS (Eq. 27)	W	0.35	0.24	0.18	0.15	0.12	0.10	0.09	0.08	0.07	0.06
MLS (Eq. 25)	W	0.19	0.14	0.12	0.10	0.09	0.08	0.08	0.07	0.07	0.06
OLS (Eq. 11)	E	0.77	0.60	0.46	0.36	0.28	0.21	0.17	0.13	0.10	0.08
Computer-assisted Process for Production Process (6402)											
MLS (Eq. 27)	W	0.62	0.45	0.34	0.26	0.21	0.17	0.13	0.11	0.09	0.07
MLS (Eq. 25)	W	0.55	0.40	0.30	0.24	0.19	0.16	0.13	0.11	0.09	0.08
OLS (Eq. 11)	W	0.88	0.73	0.58	0.44	0.33	0.24	0.18	0.12	0.09	0.06
Computer-assisted Process for Communication and Related Equipment (6403)											
MLS (Eq. 27)	E	0.72	0.52	0.38	0.27	0.20	0.14	0.10	0.08	0.05	0.04
MLS (Eq. 25)	E	0.73	0.53	0.39	0.29	0.21	0.15	0.11	0.08	0.06	0.04
OLS (Eq. 11)	W	0.92	0.76	0.57	0.40	0.25	0.15	0.08	0.04	0.02	0.01
Non-computer Assisted Process for Material Handling (6601)											
MLS (Eq. 27)	W	0.55	0.40	0.31	0.25	0.20	0.16	0.14	0.11	0.10	0.08
MLS (Eq. 25)	W	0.26	0.19	0.15	0.12	0.11	0.09	0.08	0.07	0.07	0.06
OLS (Eq. 11)	E	0.82	0.68	0.56	0.46	0.38	0.31	0.25	0.21	0.17	0.14
Non-computer Assisted Process for Production Process (6602)											
MLS (Eq. 27)	W	0.60	0.43	0.33	0.26	0.20	0.16	0.13	0.11	0.09	0.08
MLS (Eq. 25)	W	0.48	0.34	0.26	0.20	0.16	0.14	0.11	0.09	0.08	0.07
OLS (Eq. 11)	E	0.83	0.68	0.56	0.46	0.38	0.32	0.26	0.22	0.18	0.15
Non-computer Assisted Process for Communication and Related Equipment (6603)											
MLS (Eq. 27)	W	0.38	0.20	0.12	0.07	0.05	0.03	0.02	0.01	0.01	0.01
MLS (Eq. 25)	E	0.58	0.33	0.19	0.11	0.06	0.04	0.02	0.01	0.01	0.00
OLS (Eq. 11)	W	0.88	0.70	0.53	0.39	0.27	0.18	0.12	0.08	0.05	0.03
Other Machinery and Equipment (8999)											
MLS (Eq. 27)	W	0.60	0.47	0.39	0.33	0.28	0.25	0.22	0.19	0.17	0.15
MLS (Eq. 25)	W	0.55	0.43	0.36	0.31	0.27	0.24	0.21	0.19	0.17	0.16
OLS (Eq. 11)	E	0.83	0.69	0.57	0.48	0.40	0.33	0.27	0.23	0.19	0.16

Table 2.3 Ratio of the Residual Value: Structures

Asset	Model	Age of Assets								
		1yr	2yr	3yr	4yr	5yr	10yr	15yr	20yr	25yr
Plants for Manufacturing (1001)										
MLS (Eq. 27)	W	0.77	0.65	0.56	0.49	0.43	0.25	0.15	0.10	0.07
MLS (Eq. 25)	W	0.67	0.54	0.46	0.40	0.35	0.21	0.14	0.10	0.07
OLS (Eq.11)	W	0.96	0.89	0.82	0.74	0.66	0.33	0.14	0.05	0.02
Warehouses, Refrigerated Storage, Freight Terminals (1006)										
MLS (Eq. 27)	E	0.94	0.88	0.83	0.78	0.73	0.54	0.39	0.29	0.21
MLS (Eq. 25)	E	0.94	0.88	0.83	0.78	0.74	0.54	0.40	0.29	0.22
OLS (Eq. 11)	W	0.95	0.88	0.81	0.73	0.65	0.34	0.16	0.07	0.03
Maintenance Garages, Workshops, Equipment Storage Facilities (1008)										
MLS (Eq. 27)	E	0.87	0.76	0.67	0.58	0.51	0.26	0.13	0.07	0.03
MLS (Eq. 25)	E	0.88	0.77	0.67	0.59	0.51	0.26	0.14	0.07	0.04
OLS (Eq. 11)	E	0.77	0.59	0.46	0.35	0.27	0.07	0.02	0.01	0.00
Office Buildings (1013)										
MLS (Eq. 27)	E	0.93	0.86	0.80	0.74	0.68	0.47	0.32	0.22	0.15
MLS (Eq. 25)	E	0.93	0.86	0.80	0.74	0.69	0.47	0.32	0.22	0.15
OLS (Eq. 11)	W	0.96	0.91	0.85	0.79	0.72	0.44	0.25	0.13	0.07
Shopping Centers, Plazas, Malls, Stores (1016)										
MLS (Eq. 27)	E	0.95	0.90	0.86	0.81	0.77	0.60	0.46	0.36	0.28
MLS (Eq. 25)	W	0.87	0.81	0.76	0.72	0.69	0.56	0.48	0.41	0.36
OLS (Eq. 11)	E	0.92	0.84	0.77	0.70	0.64	0.41	0.27	0.17	0.11
Other Industrial and Commercial (1099)										
MLS (Eq. 27)	E	0.93	0.86	0.79	0.73	0.68	0.46	0.31	0.21	0.14
MLS (Eq. 25)	E	0.93	0.86	0.80	0.74	0.68	0.47	0.32	0.22	0.15
OLS (Eq. 11)	E	0.89	0.79	0.70	0.63	0.56	0.31	0.17	0.10	0.05
Telephone and Cablevision Lines, Underground and Marine Cables (3002)										
MLS (Eq. 27)	E	0.68	0.47	0.32	0.22	0.15	0.02	0.00	0.00	0.00
MLS (Eq. 25)	E	0.76	0.58	0.44	0.34	0.26	0.07	0.02	0.00	0.00
OLS (Eq. 11)	W	0.93	0.81	0.67	0.54	0.41	0.07	0.01	0.00	0.00
Communication Towers, Antennae, Earth Stations (3003)										
MLS (Eq. 27)	W	0.98	0.93	0.86	0.78	0.69	0.28	0.07	0.01	0.00
MLS (Eq. 25)	E	0.87	0.76	0.67	0.58	0.51	0.26	0.13	0.07	0.03
OLS (Eq. 11)	E	0.73	0.53	0.38	0.28	0.20	0.04	0.01	0.00	0.00

model (equation 11) represents a comparatively simple (linear) formulation based strictly on the vector of average prices (where each price represents an average survival ratio given by equation 15). We have no strong priors as to whether this OLS specification will yield substantially different depreciation profiles than the more complex non-linear formulations represented by equations 25 and 27. Both our "final" rounding-corrected specification (equation 27) and our "intermediate" uncorrected specification (equation 25) are reported here in order to quantify the significance of digit preference (i.e., age-rounding) in our micro data. We discuss results for machinery and equipment and structures in turn.

Many assets in the machinery and equipment class exhibit substantial reductions in asset value early in service life (Table 2.2). To see this, consider the results of our rounding-corrected ML model (equation 27). Sixty-percent of the machinery and equipment assets studied (15 of 25) surpass their median survival value—the point at which one-half of total economic value is lost—prior to their 4th year of service life. Only 2 asset categories (ships and boats and aircraft) retain 50% of their value after 5 years. Assets for which large numbers of observations exist—e.g., computers (2,484), office furniture (2,651) and automobiles (2,554)—exhibit accelerated depreciation profiles. For computers, only a small residual of total value (6%) remains after the 5th year of operation.

In the main, large reductions in economic value for machinery and equipment assets accord with our expectations. For certain assets in this class, (e.g.) automobiles and computers, there is much evidence to suggest that the onset of economic depreciation is rapid.

High levels of depreciation are not unique to assets in the machinery and equipment class. Several of the assets in the structures class (Table 2.3) also exhibit this pattern. Plants for manufacturing—the asset category with the largest number of observations in this class—exhibit a highly accelerated depreciation profile. According to our rounding-corrected model (equation 27), only 43% of the total plant value remains after the 5th year of operation, and only one-quarter of total value survives the first decade of service life. While other large-sample assets (e.g., warehouses and office buildings) exhibit less precipitous reductions in asset value, there is evidence that the overall magnitude of economic depreciation is nonetheless substantial. To see this, we can focus on estimated survival rates after a decade of service life. Warehouses retain slightly more than their median survival value (the point at which one-half of total value is exhausted), while office buildings eclipse their median survival value by their tenth year of operation.

High levels of depreciation among structures are not, in our view, counterintuitive. On this, the case of plants is illustrative. First, there is anecdotal evidence that plant depreciation is relatively high due to changes in technology. Second, many of their production characteristics are idiosyncratic. In many situations, the production characteristics of a plant are not readily transferable from existing owners to new owners, that is, from current-use to future-use. If prospective owners expect to incur high retooling and refitting costs, the current market value of the plant (based, in part, on what the new owner is willing to pay) may be substantially diminished. These situations reinforce the price concept being evaluated herein: estimates of depreciation are based on market prices, observed as assets are transferred from owner-to-owner, and not on reservation prices, which identify the value of the asset to its current owner (i.e., in its current productive use).

While many of our results suggest that the magnitude of economic depreciation is substantial, evidence on whether rates of depreciation are age-invariant or variable over the course of service life is, on balance, mixed. To see this, we again focus on our final, rounding-corrected, ML specification (equation 27). Statistical grounds for rejecting the null of an age-invariant rate were apparent for only 2 of 8 structures and 12 of the 25 machinery and equipment assets considered herein.

We have based our discussion of results on what, in our view, represents the (theoretically) optimal estimation vehicle—the rounding-corrected model described by equation 27. However, differences in estimated profiles within an asset class can occasionally be striking (e.g., see results for plants (1001) and towers (3003) in the structures class, along with office furniture (6001) and non-computer assisted process for production (6602) in the machinery and equipment class).

We expect to observe differences between our OLS average-price and MLS formulations because the methodological underpinnings of each are quite distinct. As outlined in Section 2.4, the average-price model is a simple linear transformation of the Weibull survivor function, and is estimated from weighted survival ratios. By contrast, the ML model is based on an explicit survival formulation that fully integrates all micro-information from the asset samples. In many cases, the linear model yields substantially higher SFEs than the MLS model (e.g., computer and non-computers assisted processes and motors). In a more limited number of cases, the linear model generates higher levels of depreciation (e.g., pollution abatement equipment and buses).

Comparisons between the two ML formulations are of a more direct nature—as they simply quantify the bias of age-rounding. For the majority of assets in our sample, the rounding-corrected and uncorrected ML models yield very similar results (e.g., heavy construction equipment and capitalized tooling equipment), or unearth only qualitatively modest differences (e.g., heating equipment). In some cases, however, the impact of age bias on the depreciation estimates is substantial—typically bringing about more acceleration in the uncorrected depreciation profile (e.g. office furniture, motors and trucks). Higher survival rates in the presence of digit preference are less common (e.g., non-computer assisted processes for communications and telephone lines).

2.5.2 Econometric versus Non-econometric Results: Select Assets

For many of the assets studied, our ML survival model generates accelerated depreciation profiles. All comparisons to this point, however, have been based on alternative formulations of our econometric framework. In this section, we compare two of these econometric results—the OLS average price model (equation 11) and the rounding-corrected ML model (equation 27)—to two non-econometric profiles, first, an actual age-price profile represented by the vector of observed prices at different ages $\bar{R}(t)$, and second, a geometric profile based on the *ex ante* accounting method described by equation 4. The first of these non-econometric approaches, the age-price profile, is the locus of average survival ratios, each of which constitutes an independent point-estimate at some corresponding age. This profile, then, does not represent a survival curve, in the sense that there is no mathematical relationship between subsequent point estimates (a mathematical property of survival curves).

By contrast, the second of these non-econometric approaches, the geometric profile, does represent a survival curve that is directly comparable to our econometric estimates. To calculate this profile from equation 4, we calculate rates of depreciation by

Figure 2.3 Comparative Depreciation Profiles: Computers, Associated Hardware and Word Processors

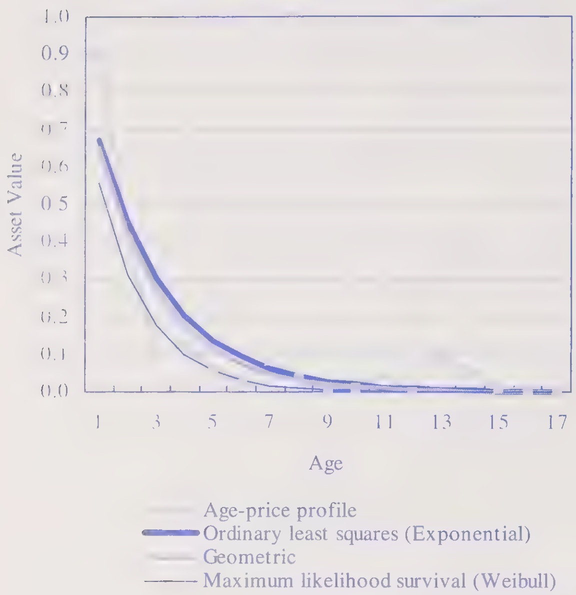
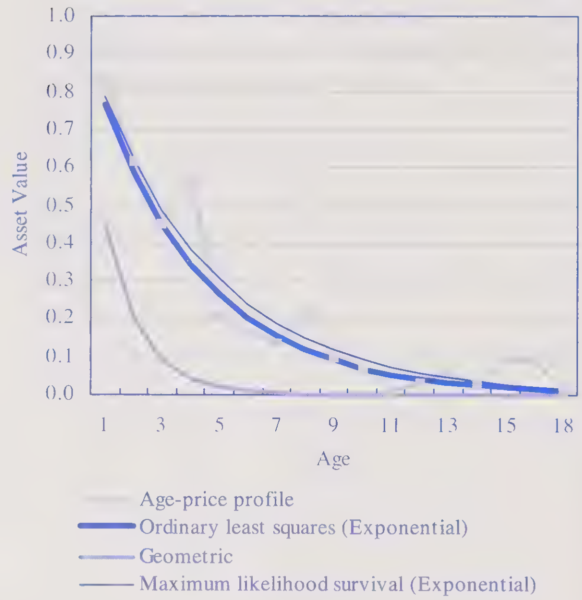


Figure 2.4 Comparative Depreciation Profiles: Automobiles and Major Replacement Parts



assuming BEA-style values for the declining-balance rate (*DBR*=1.65 for machinery and equipment and 0.91 for structures) and obtaining asset-specific estimates of mean service life from the Capital and Repair Expenditures Survey.[23] We then used the indirect rate of depreciation, calculated from equation 4, to plot the subsequent profile.

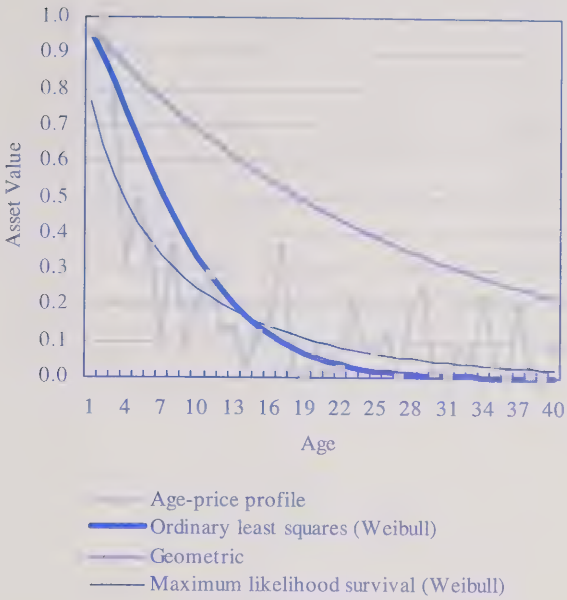
We present these results graphically for two machinery and equipment assets, computers and automobiles, and one asset in the structures class, plants for manufacturing.

Comparative depreciation profiles for computers are examined in Figure 2.3. The vector of reported survival ratios $R(t1),...,R(n)$ that traces out the age-price profile is represented by the heavy solid line. This non-econometric age-price plot provides some initial evidence of large declines in asset value during early stages of service life. Our OLS average-price model (equation 11) is estimated directly from this age-price plot and generates depreciation estimates that are very similar to our *ex ante* geometric accounting method (equation 4). Our rounding-corrected maximum-likelihood model (equation 27) produces a depreciation profile with higher reductions in asset value early in service life. This maximum likelihood formulation provides evidence of a variable depreciation rate, while the OLS model supports the null of a constant rate.

Depreciation estimates for automobiles are examined in Figure 2.4. Once again, the reported age-price profile indicates that large reductions in asset value occur early in service life. In this case, both econometric techniques produce very similar profiles—which closely track average prices. The OLS and ML survival models also provide evidence of a constant, age-invariant depreciation rate. While the *ex ante* geometric method also (by design) generates a constant rate, it yields very different depreciation

[23] Data on service lives was obtained for the period 1995-1997. Mean service lives are investment-weighted.

Figure 2.5 Comparative Depreciation Profiles: Manufacturing Plants



estimates than either of our econometric techniques. These rapid declines in asset value come about because of low estimates of service life (an average of 3.0 years).

For plants, the age-price plot traced out by the average survival ratios $\bar{R}(t1),...,R(n)$ is comparatively volatile—with substantial fluctuations in asset value at mid-to-late stages of service life (Figure 2.5). The OLS-based depreciation profile generated directly from these average price ratios produces a highly-accelerated pattern with steep declines in asset value. Rates of depreciation from the OLS model are variable at different stages of the lifecycle. The OLS profile reaches its asymptote (with virtually all survival value exhausted) at a service life of about 25 years. The depreciation profile generated by our ML survival model is also accelerated—but with more rapid declines in asset value early in service life. While this profile also declines at a variable rate, reductions in value during mid-to-late stages of the lifecycle are more modest than in the OLS case. Our non-econometric geometric profile—based on BEA-style values for the declining-balance rate and recent data on service life—again differs substantially from our econometric results. This *ex ante* geometric technique produces a low depreciation rate (and correspondingly high survival function estimates), due to a combination of a low *DBR* (0.91) and a long estimated service life (24.7 years).

The above results are based on survival curves—a locus of probability estimates that track changes in asset value at various stages of service life. One advantage of the parametric distributions utilized herein (i.e., Weibull, exponential and geometric) is that all allow for the straightforward derivation of summary measures that can be used to compare the various depreciation profiles. We examine one such measure below.

2.5.3 Mean Value-life

To compare differences in depreciation profiles, we calculate the asset's *mean value life*—a simple measure of central tendency, expressed in years, that reflects observed changes in valuation at all stages of an asset's lifecycle. For our econometric estimates of depreciation, mean value-life is just the estimated mean of the survival distribution. When depreciation profiles are based on the Weibull, or age-variant, version of our model, this mean value-life is

$$MVL = \frac{1}{\lambda}\Gamma[(\rho+1)/\rho]. \quad (28)$$

For the exponential (restricted) version of our model, the mean is

$$MVL = \frac{1}{\lambda}. \tag{29}$$

A comparable measure of central tendency can also be derived from our non-econometric accounting framework. Recall the rate of geometric depreciation from equation 4 is just

$$\delta = \frac{DBR}{L} \tag{30}$$

which determines the curvature of the subsequent depreciation profile. The mean of the geometric profile is just the inverse of the rate,

$$\mu = \frac{1}{\delta} \tag{31}$$

or equivalently,

$$\mu = \frac{L}{DBR}. \tag{32}$$

Equation 32 is illuminating because it indicates how relationships between economic value and physical service life are affected by the declining balance rate. If the *DBR* equals unity, mean value-life is equal to service life. Similar, for values of *DBR* greater than unity, the mean value-life (conceptually a measure of central tendency) is less than estimated service life. Equation 32 thus provides us with a price, or value, based concept from the geometric accounting framework that is comparable to equations 28 and 29.

We examine differences in mean value-life in tables 2.4 and 2.5. Once again, we report estimates from our two econometric techniques—the OLS and MLS models described by equations 11 and 27—along with non-econometric results based on equation 32. Here, we offer two non-econometric estimates of mean life—first, using the more traditional double-declining balance rate, and second, using BEA-style values for the declining balance rate (which were used to derive the geometric profiles in Section 2.5.2).

We observed earlier that our ML survival model (equation 27) often generates high rates of economic depreciation. We can assess this further by comparing summary statistics from this model with those derived from the double-declining geometric method—the version of our *ex ante* formulation (equation 32) that generates the highest levels of depreciation—and testing for differences. For a slight majority of machinery and equipment assets (14 of 25), the mean-value life estimates generated from the ML survival model are significantly shorter than those generated via the double-declining balance method (Table 2.4). Conversely, there are only 4 machinery and equipment assets for which our rounding-corrected ML survival formulation produces significantly longer summary measures than the double-declining method.

Table 2.4 Mean Value-life in Years: Machinery and Equipment (Confidence Intervals in Parentheses)

	OLS	MLS	Geometric DBR=2	Geometric DBR=1.65
Office Furniture, Furnishings (6001)	4.7 (3.3, 6.1)	3.3 (3.2, 3.5)	3.0 (3.0, 3.1)	3.7 (3.6, 3.7)
Computers, Associated Hardware and Word Processors (6002)	2.5 (1.3, 3.7)	1.7 (1.7, 1.8)	2.3 (2.3, 2.4)	2.8 (2.8, 2.9)
Non-office Furniture, Furnishings and Fixtures (6003)	4.8 (3.1, 6.6)	4.7 (4.5, 5.0)	4.0 (3.9, 4.1)	4.8 (4.7, 4.9)
Scientific, Professional and Medical Devices (6004)	5.3 (3.9, 6.6)	3.9 (3.8, 4.1)	5.1 (5.0, 5.3)	6.2 (6.0, 6.5)
Heating, Electrical, Plumbing, Air Conditioning and Refrigeration Equipment (6005)	4.4 (3.4, 5.4)	3.7 (3.4, 4.1)	6.4 (6.2, 6.6)	7.8 (7.5, 8.0)
Pollution Abatement and Control Equipment (6006)	1.9 (1.2, 2.7)	4.5 (3.7, 5.2)	8.8 (8.5, 9.1)	10.7 (10.4, 11.0)
Safety and Security Equipment (6007)	1.8 (1.1, 2.5)	2.2 (1.8, 2.6)	5.1 (4.9, 5.4)	6.2 (5.9, 6.5)
Motors, Generators, Transformers, Turbines, Compressors and Pumps of all types (6009)	7.2 (5.7, 8.8)	4.0 (3.6, 4.5)	11.9 (11.5, 12.3)	14.4 (13.9, 14.9)
Heavy Construction Equipment (6010)	5.5 (4.0, 7.0)	5.2 (4.8, 5.6)	3.6 (3.4, 3.9)	4.4 (4.1, 4.7)
Tractors and Other Field Equipment (6011)	5.3 (3.3, 7.3)	5.2 (4.7, 5.7)	6.6 (6.1, 7.2)	8.0 (7.4, 8.7)
Capitalized Tooling and Other Tools (6012)	4.4 (2.9, 5.9)	2.0 (1.8, 2.1)	3.4 (3.2, 3.5)	4.1 (3.9, 4.3)
Drilling and Blasting Equipment (6013)	5.1 (3.7, 6.6)	4.6 (3.8, 5.4)	5.8 (5.1, 6.6)	7.0 (6.2, 8.0)
Automobiles and Major Replacement Parts (6201)	3.8 (2.1, 5.4)	4.2 (4.0, 4.3)	1.5 (1.5, 1.5)	1.8 (1.8, 1.8)
Buses (all types) and Other Field Equipment (6202)	3.0 (0.5, 5.5)	5.0 (4.3, 5.7)	5.8 (5.1, 6.5)	7.0 (6.2, 7.9)
Trucks, Vans, Truck Tractors, Truck Trailers and Major Replacement Parts (6203)	5.1 (3.1, 7.0)	4.2 (4.0, 4.3)	2.8 (2.7, 2.8)	3.4 (3.3, 3.4)
Locomotives, Rolling Stock, Street and Subway Cars, Other Rapid Transit and Major Parts (6205)	4.7 (3.2, 6.2)	6.2 (5.3, 7.0)	10.1 (9.7, 10.5)	12.2 (11.8, 12.7)
Ships and Boats and Major Replacement Parts (6206)	7.4 (5.1, 9.6)	9.1 (7.3, 10.8)	8.1 (6.4, 10.1)	9.8 (7.8, 12.3)
Aircraft, Helicopters, Aircraft Engines and Other Major Replacement Parts (6207)	12.7 (7.3, 18.1)	15.0 (14.2, 15.9)	8.9 (8.6, 9.2)	10.8 (10.5, 11.1)
Other Transportation Equipment (6299)	3.9 (2.4, 5.4)	2.5 (1.6, 3.5)	3.5 (3.2, 3.8)	4.2 (3.9, 4.6)
Computer-assisted Process for Production Process (6402)	4.3 (3.2, 5.3)	3.3 (2.9, 3.6)	5.7 (5.5, 5.9)	6.9 (6.7, 7.1)
Computer-assisted Process for Communication and Related Equipment (6403)	3.7 (2.8, 4.7)	3.1 (2.7, 3.5)	5.4 (5.2, 5.6)	6.5 (6.4, 6.7)
Non-computer Assisted Process for Material Handling (6601)	5.1 (3.3, 6.9)	3.3 (3.0, 3.7)	5.0 (4.9, 5.2)	6.1 (5.9, 6.3)
Non-computer Assisted Process for Production Process (6602)	5.2 (3.7, 6.8)	3.3 (3.1, 3.4)	6.6 (6.5, 6.7)	8.0 (7.8, 8.1)
Non-computer Assisted Process for Communication and Related Equipment (6603)	3.8 (2.8, 4.7)	1.3 (1.1, 1.4)	4.4 (4.2, 4.5)	5.3 (5.1, 5.5)
Other Machinery and Equipment (8999)	5.4 (3.6, 7.3)	5.4 (4.7, 6.1)	4.4 (4.1, 4.7)	5.3 (5.0, 5.7)

Table 2.5 Mean Value-life in Years: Structures (Confidence Intervals in Parentheses)

	OLS	MLS	Geometric DBR=2	Geometric DBR=0.91
Plants for Manufacturing (1001)	8.5 (6.9, 10.1)	7.7 (7.0, 8.5)	12.3 (12.0, 12.7)	27.1 (26.5, 27.8)
Warehouses, Refrigerated Storage, Freight Terminals (1006)	8.7 (6.9, 10.5)	16.1 (14.1, 18.0)	12.7 (12.2, 13.3)	28.0 (26.8, 29.1)
Maintenance Garages, Workshops, Equipment Storage Facilities (1008)	3.8 (2.6, 5.1)	7.4 (6.3, 8.6)	13.1 (12.6, 13.7)	28.9 (27.7, 30.1)
Office Buildings (1013)	10.8 (8.5, 13.1)	13.2 (12.2, 14.2)	12.7 (12.3, 13.1)	27.9 (27.1, 28.8)
Shopping Centers, Plazas, Malls, Stores (1016)	11.4 (7.0, 15.7)	19.4 (16.7, 22.1)	13.3 (12.6, 14.0)	29.1 (27.6, 30.8)
Other Industrial and Commercial (1099)	8.6 (6.0, 11.2)	12.9 (11.0, 14.9)	12.3 (11.6, 13.1)	27.1 (25.4, 28.9)
Telephone and Cablevision Lines, Underground and Marine Cables (3002)	4.8 (3.7, 6.0)	2.6 (2.2, 3.0)	9.2 (8.6, 9.7)	20.1 (18.9, 21.4)
Communication Towers, Antennae, Earth Stations (3003)	3.1 (2.0, 4.3)	7.8 (7.0, 8.5)	6.5 (6.2, 6.7)	14.2 (13.6, 14.8)

For one-half of the structures evaluated herein (4 of 8), mean-value lives from the ML survival model are significantly shorter than those generated via the double-declining method (Table 2.5). In 2 of 8 cases (office buildings and other industrial structures) differences in these summary measures are not quantitatively meaningful. In two other cases (warehouses, shopping centers), our ML survival model generates significantly longer estimates of economic life than the double-declining method. However, *both* the econometric and double-declining estimates of mean-value life are much lower than those generated via the geometric approach when BEA-style assumptions about the *DBR* are used in place of the double-declining rate of two.[24] In all cases, this BEA-style geometric method produces much lower rates of depreciation.

In what follows, we place comparisons between our MLS technique and these *ex ante* methods in a larger context—by evaluating their impact on the estimation of capital stock.

2.6 Capital Stock

2.6.1 Perpetual Inventory Estimates of Capital Stock

In this section, we generate estimates of capital stock based on our rounding-corrected ML survival model, and compare these to two different stock estimates based on *ex ante* depreciation methods (represented by equation 4). Estimates of capital stock are based on the perpetual inventory model

$$K(t) = I(t) + (1-\delta)K(t-1) \tag{33}$$

[24] Note from equation 32 that an asset's mean-value life μ—generated from the geometric depreciation profile—is longer than service life L when adopting a BEA-style *DBR* of 0.91 for structures.

where δ represents a (constant) geometric rate of depreciation that proxies the rate of replacement.

To produce econometric estimates of δ ,we estimated the restricted (exponential) form of our rounding-corrected model (equation 27) for 59 individual assets and 5 asset combinations[25], and then used the estimated depreciation rates from this model to construct aggregate summary rates of depreciation for 19 different Hicksian asset groups—6 asset groups for structures and 13 asset groups for machinery and equipment.[26] These 19 asset groups were derived using historical information on service life.

We report depreciation rates for these asset groups in Appendix 2.C.

In what follows, we report two sets of estimates from our maximum-likelihood survival model. The first estimate is based on the full sample of individual prices, employing all useable information on selling prices and discards. The second estimate is based on a reduced sample of observations in which (i) a subset of zero prices (i.e., discards) has been eliminated and (ii) select adjustments have been made to different asset-specific depreciation rates. This second approach was used to generate depreciation rates for Statistics Canada's most recent set of multifactor productivity estimates. We discuss these adjustments in more detail in Appendix 2.C.

We also generate stock estimates using depreciation rates from *ex ante* geometric accounting techniques. As in Section 2.5, we based these rates of depreciation on estimates of mean service life from Statistics Canada's *Capital and Repair Expenditures Survey*. Investment-weighted service lives were calculated over the 1995-1997 period for each of the asset categories required for the perpetual inventory calculation. Two different sets of depreciation estimates were then generated using different assumptions about the declining balance rate. First, we assumed a traditional double-declining rate of 2 for both machinery and equipment and structures. Second, we used BEA-style values of 1.65 for machinery and equipment assets and 0.91 for structures.

We present our stock estimates in Figure 2.6. Note that these estimates are generated strictly for expositional purposes.

The *ex ante* BEA-style depreciation estimates produce the largest stock estimates over the 1961-1996 period, followed by the *ex ante* double-declining approach. The exponential rates of depreciation generated by our econometric model generate the lowest stock levels over this period—using either the reduced sample (see Appendix 2.C) or all information on discards. We assess the level of precision inherent in our econometric technique by calculating 5% confidence intervals around the stock estimates. We present these graphically around the reduced-sample stock estimate in Figure 2.6. These upper and lower-bounds are virtually identical to the corresponding estimate. Hence, our MLS estimation framework yields very precise estimates of capital stock.

[25] In certain cases, we estimated econometric rates of depreciation for various asset combinations in order to overcome sample limitations. Five such combinations were estimated, containing price information on 52 individual assets.

[26] Because our principal objective at this stage was to produce depreciation rates for aggregate asset groupings, we were able to use more information on individual assets from our database. To produce summary rates of depreciation for the 19 asset groups, we utilized over 27,300 observations on 111 individual assets. For assets with large numbers of observations, we also estimated rates of depreciation for different industry groupings.

Figure 2.6 Comparative Estimates of Capital Stock (1992 Prices)

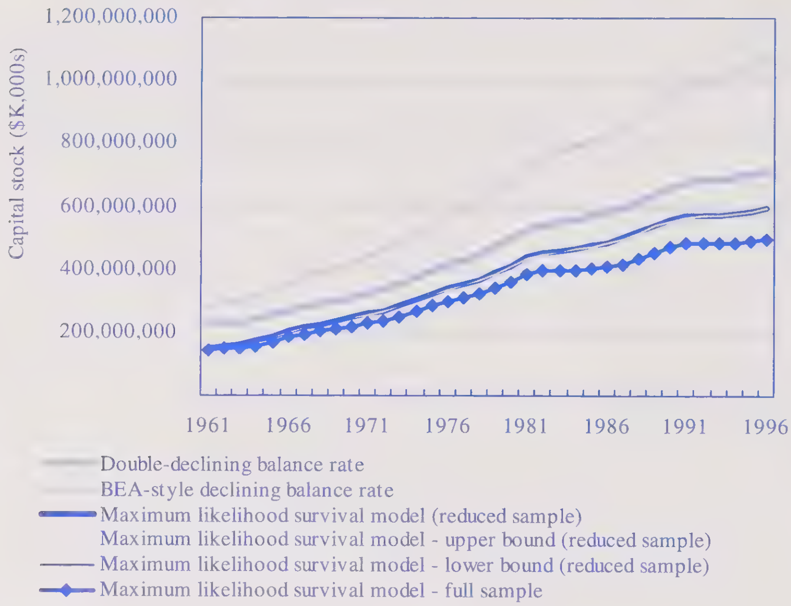


Figure 2.7 Normalized Stock Estimates

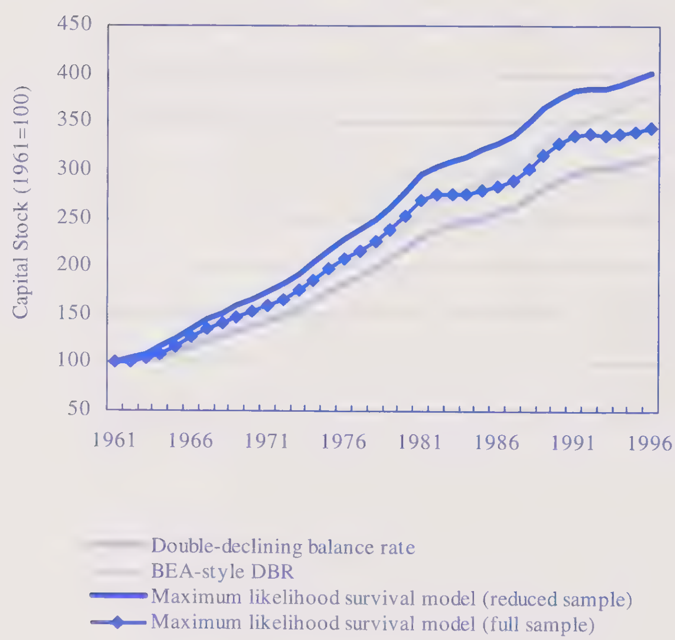


Table 2.6 Comparative Growth Rates in Real Capital Stock Under Alternative Depreciation Regimes (%)				
	BEA-style DBR	**DDBR**	**MLS Model** (full sample)	**MLS Model** (reduced sample)
Growth Rate (1961-1995)	3.89	3.32	3.60	4.05
Structures	4.53	4.12	4.78	5.06
Machinery and Equipment	3.73	3.07	3.10	3.63

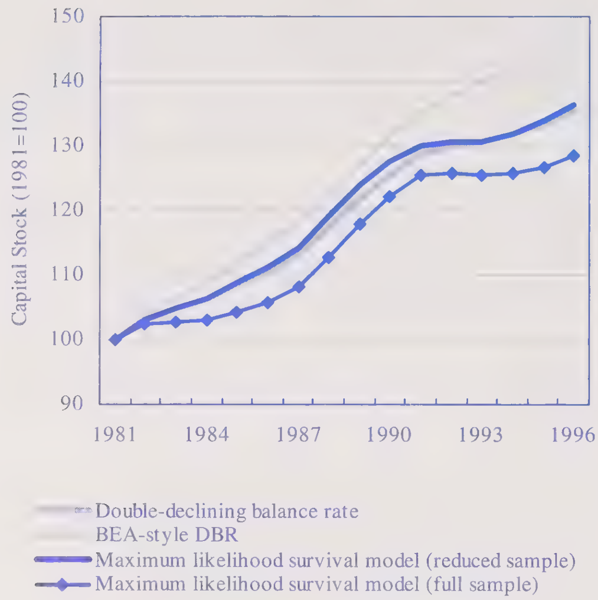
We now turn to consider patterns of capital growth. Multifactor productivity estimates, key performance indicators, are based on rates of growth in factor inputs, not on the value, or level, of inputs in any one period. Differences in levels of capital stock depicted in Figure 2.6 may obscure differences in patterns of capital growth—because each estimate assumes a different starting level in 1961. To compare the impact of our depreciation techniques on the growth of capital stock, we first normalized each stock estimate to a value of 100 in 1961. The resulting growth profiles are presented in Figure 2.7 and Table 2.6.

The *ex ante* double-declining approach generates the lowest growth path over the 1961-1996 period, with an annual growth rate of 3.3% By comparison, growth rates using the ML survival (full sample) and BEA-style depreciation techniques are 3.6% and 3.9%, respectively. These latter two depreciation techniques generate faster, and quite similar, growth trends over the pre-1980 period. After 1980, however, depreciation estimates from the ML survival model (full sample) produce growth patterns that are more comparable to those generated via the double-declining method. The growth in capital stock slows during the early-to-mid 1980s, and then again after 1991—trends that are particularly apparent in our econometric-based estimates. This apparent decline in stock growth coincides with years in which gross investment ratios—investment expressed as a percentage of GDP—are also in relative decline (Baldwin et al., 2001). These post-1980 slowdowns are not apparent when using the BEA-style depreciation estimates—as the evolution of capital stock largely mirrors its pre-1980 trend. The growth profile from the ML survival model (reduced sample) also mirrors the trend generated via double-declining depreciation. This estimation approach yields a higher rate of capital growth (4.1%) than any of the other depreciation estimates presented herein.

The results of the above exercise suggest that our *ex post* survival model gives rise to higher capital stock growth rates—at least when compared to the more traditional double-declining method of depreciation. While the econometric estimates of depreciation for individual assets in our sample often generate accelerated declines in asset value, these do not bring about precipitous reductions in capital growth when our technique is integrated into the perpetual inventory framework. The relationship between asset-specific rates of depreciation and the overall stock estimates is not straightforward; it depends how the individual asset classes are aggregated, and, in turn, how these aggregate groupings are weighted when generating the capital stock estimate.

It should be stressed, however, that the above conclusions about relative long-run growth paths are contingent upon the year at which stock levels are normalized. We have selected 1961 as our start point for these capital stock exercises as our interest lies, initially, in characterizing long-run trends. If we select another, more current, year as our basis for normalization—for instance, 1981—different conclusions may emerge. We examine these alternative growth paths based on 1981 normalization in Figure 2.8.

Figure 2.8 Normalized Stock Estimates



In this more recent period, the alternative depreciation techniques generate a different set of impressions regarding the growth of capital stock. BEA-style depreciation rates give rise to a significantly higher rate of capital growth (an average annual rate of 2.6%) than other depreciation methods. The depreciation estimates from our MLS survival model (reduced sample) generate a growth profile over this more recent period that is very similar to that generated via the *ex ante* double-declining estimates (both yield a growth rate of 2.1%). The MLS estimates based on full price samples generate the lowest growth rate at 1.7%.

2.7 Conclusion

In this chapter, we use Weibull survival models to estimate patterns of economic depreciation based on rich samples of used-asset prices and discards. Three variants of our estimation framework were proposed: a simple linear model estimated via average prices, and two-maximum likelihood models that generate depreciation estimates directly from samples of micro-data. Our second maximum likelihood formulation adjusts for patterns of digit preference.

The depreciation profiles generated by our econometric techniques are, on balance, accelerated, producing convex age-price curves. Substantial reductions in economic value are apparent early in life for many assets in the machinery and equipment class, as well as for certain structures. Evidence that rates of depreciation are constant over service life is, on balance, mixed.

Differences in the econometric formulation of our Weibull survival model can give rise to discordant impressions of how rapidly asset values erode over the course of service life. In our view, the rounding-corrected maximum likelihood specification should be viewed as the optimal estimation vehicle—as it makes full use of sample information *and* accounts for patterns of age-rounding in the price data. Comparisons between our MLS model and *ex ante* geometric approaches reveal, first, that our econometric techniques generate comparably high levels of depreciation, and second, that *ex ante* rates are particularly sensitive to the choice of declining-balance rate.

We then compared our econometric approach to *ex ante* geometric methods by generating different estimates of capital stock. To do so, we estimated a restricted (exponential) version of our rounding-corrected survival model and produced aggregate depreciation rates for different asset classes. We generated two capital stock estimates from our econometric approach—the first using all useable information on prices and discards and the second using more restricted data samples that eliminate potentially

spurious information on discards. This latter approach also included several adjustments to our econometric depreciation rates.

We then calculated geometric *ex ante* rates of depreciation for our asset classes, using different assumptions about the declining balance rate, and compared the subsequent stock estimates. When capital stock levels are examined over the 1961-1996 period, our econometric approach generates lower stock estimates than those generated by *ex ante* geometric techniques. When levels are normalized to examine differences in secular growth rates over this period, our econometric approach yields higher rates of capital growth than that generated via double-declining geometric depreciation.

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Appendix 2.A: Outlier Identification and Edit Strategy

In preparing our asset samples for estimation, we identified subsets of records that, relative to the majority of observations in their asset categories, exhibited either highly undervalued resale prices in early stages of service life, or highly overvalued resale prices at late stages. As noted in Section 2.3, we removed these outlier observations from our asset samples. In principle, we could identify outliers on an asset-by-asset basis via visual examinations of age-survival plots. However, this entails a high degree of subjective judgement, and may give rise to inconsistencies in the treatment of certain types of observations across asset categories. Consequently, we based our method of identification on a set of systematic rules. These are described below.

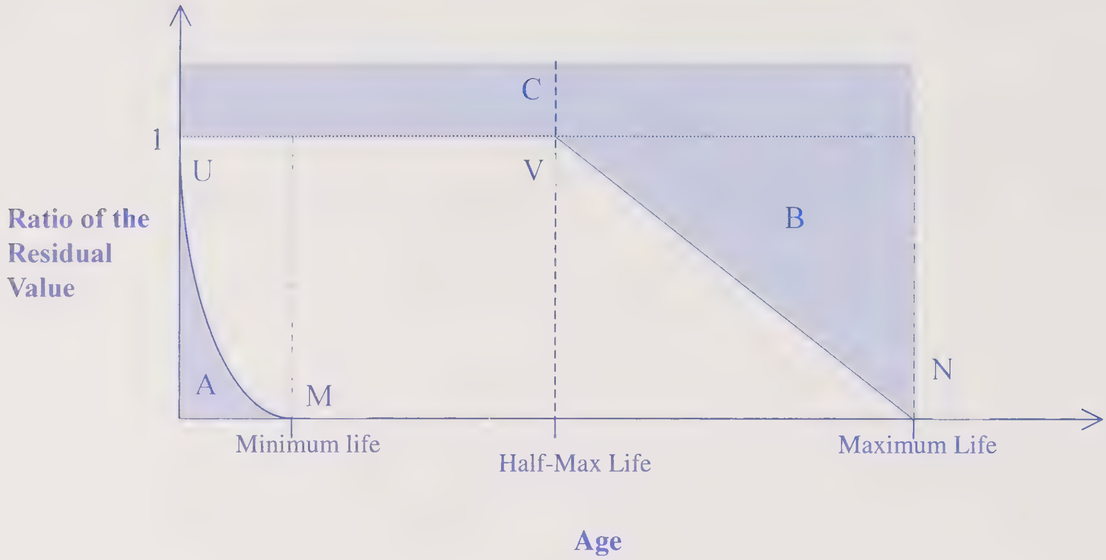
First, we calculate minimum and maximum survival times for a given asset using information on discards—observations with a selling price of zero, but with information on gross book value and age. We begin by assuming that the retirement age of an asset (expressed in log form) follows a normal distribution. We represent this graphically in Figure 2.A1. The lower and upper bounds correspond to the youngest and oldest retirement ages at the 10% confidence level. Minimal survival time is defined at the lower bound, and maximum survival time is defined at the upper bound weighted by an adjustment factor of 1.2.[27]

All observations in areas A, B and C are removed from sample. Area A includes observations which have "unreasonably low" survival rates at an early age. This area is bounded by a quadratic frontier connecting point U (the "start" point[28]) and the minimum age M (i.e., the lower boundary below which zero sale prices are rejected). Area B includes observations which have "unreasonably high" survival rates well into their service life. This area is bounded by a linear frontier connecting point V (corresponding to a survival rate that equals one-half of maximum life) and point N (maximum life). Area C identifies all observations with survival rates greater than one (i.e., assets that appreciate in constant dollars).

[27] This weighting adjustment was made in order to define roughly symmetrical rejection areas on both sides of the distribution.

[28] That is, the point corresponding to a zero age and a survival rate of unity.

Figure 2.A1: Outlier Identification



Appendix 2.B: Generalized Residuals, Specification and Heterogeneity Tests

Following Lancaster (1985a), we made use of generalized residuals to develop specification and heterogeneity tests.

Using the fact that integrated hazards are generalized errors and that their distribution is unit exponential, Lancaster used the moment generating functions $\varepsilon(t)$ and log $\varepsilon(t)$ to build specification tests for any distribution used in survival analysis. In the case of uncensored data, integrated hazards computed from maximum likelihood estimates provide the generalized residuals $e(t)$. Accordingly, for the Weibull distribution

$$f(t) = (\lambda t)^{\rho-1} \lambda\rho \exp(-\lambda t)^{\rho} \tag{B1}$$

The generalized residuals are computed as

$$e(t) = \left(\hat{\lambda} t_i\right)^{\hat{\rho}} \tag{B2}$$

where $\hat{\lambda}$ and $\hat{\rho}$ are ML estimators.

In the case of right censoring Lancaster (1985b)[29] derived the generalized residual from the ML estimates of the conditional mean of the generalized error. He used the expectation

$$E(\varepsilon(T) \mid T > s) \tag{B3}$$

where T denotes the random variable and s the censoring time.

Given $f(t)$, the density function of $\varepsilon(t)$ (unit exponential) and $\Pr(T>s)$ the probability that T exceeds s, the conditional expectation becomes

[29] The formulation used by Lancaster for the Weibull distribution is slightly different from ours. In his case, the exponent ρ applies only to t, the time variable.

$$E(\varepsilon(T) \mid T > s) = \int_{s}^{\infty} \frac{\varepsilon(t) f(\varepsilon(t))}{\Pr(T > s)} = \tag{B4}$$

$$\int_{s}^{\infty} \frac{\varepsilon(t)\exp(-\varepsilon(t))}{\exp(-\varepsilon(s))} d\varepsilon(t) \quad \left. \frac{-\exp(-\varepsilon(t)) - \varepsilon(t)\exp(-\varepsilon(t))}{\exp(-\varepsilon(s))} \right|_{s}^{+\infty} = 1 + \varepsilon(s)$$

Using the same approach, we now derive the generalized error in the case of left censoring. We have[30]

$$E(\varepsilon(T) \mid T < s) = \int_{0}^{s} \frac{\varepsilon(t) f(\varepsilon(t))}{\Pr(T < s)} = \int_{0}^{s} \frac{\varepsilon(t)\exp(-\varepsilon(t))}{1-\exp(-\varepsilon(s))} d\varepsilon(t) = \tag{B5}$$

$$\left. \frac{-\exp(-\varepsilon(t)) - \varepsilon(t)\exp(-\varepsilon(t))}{1-\exp(-\varepsilon(s))} \right|_{0}^{s} = 1 - \frac{\varepsilon(s)\exp(-\varepsilon(s))}{1-\exp(-\varepsilon(s))}$$

from which generalized residuals are computed. Recall that our maximum likelihood function has the general form

$$L = \Sigma_i \, w_i \left[(1 - R_i) \, F(t_i) - R_i \; S(t_i) \right] \tag{B6}$$

where R_i is the survival (price) ratio, w_i the constant dollar weight, and $F(t_i)$ and $S(t_i)$ represent the cumulative density and survivor functions, respectively. Because of the double-censoring specification, all observed times are treated as censoring times. The generalized residual becomes a mixture of equations B5 and B6. We have

$$\hat{e} = (1 - R_i) \left\{ 1 - \frac{\varepsilon(t_i)\exp(-\varepsilon(t_i))}{1 - \exp(-\varepsilon(t_i))} \right\} + R_i (1 + \varepsilon(t_i)) . \tag{B7}$$

Using the ML estimators from the Weibull distribution, it can be shown that the weighted mean of the residuals equals unity. Following the methodology proposed by Tauchen (1985), and developed by Pagan and Vella (1989), Jaggia (1991a, 1991b) developed tests for specification and heterogeneity of duration models. The advantage of this methodology is that it takes into account the possible correlation between the tests. Given that the generalized residuals are unit exponential, their theoretical moments are known, and any combination of different moments can be used for the construction of a test.[31]

The test statistic that we used to evaluate heterogeneity and specification is

$$\chi^2{}_k = RW\,'M\,(M\,'M - M\,'D(D'D)^{-1} D'M\,)^{-1} M\,'RW \tag{B8}$$

[30] We use the identity $\int xe^{-x} dx = -e^{-x} - xe^{-x}$.

[31] Kiefer (1985) proposed the use of Laguerre polynomials in a similar construction.

where k is the number of moments tested simultaneously and RW is a column vector of length n containing the square root of the weights. M is n x k matrix of the individual terms in the moment, while D is the empirical gradient of the maximum likelihood function. For M and D, individual elements are pre-multiplied by the square root of the weight so that the χ^2 statistics respect the weighting system.

Two joint tests were built in order to test for specification and heterogeneity. The nulls were always strongly rejected.

The implications of our heterogeneity and specification tests need to be set in context. Our rationale for specifying a Weibull-based survival model is that *a priori* it yields an analytically sensible characterization of the depreciation process—one that can easily be reconciled with standard geometric accounting methods. While our statistical tests do not provide evidence for the Weibull, it may be difficult to define a more appropriate *generalized* parametric framework, if asset-specific depreciation profiles are highly heterogeneous. We do not have strong priors that the adoption of an alternative, more sophisticated, parametric form would improve our results significantly. As Heckman and Singer (1984) note, one runs the risk of over-parameterizing the model without concomitant gains in explanation.

An alternative approach is to move away from a generalized parametric framework—in favour of defining different parametric models on an asset-to-asset basis. This, however, may complicate many of our analytics—and render comparability difficult. In addition, it would sever the conceptual linkage between our exponential (i.e., restricted Weibull) estimates of economic depreciation and the rates of replacement that are used to generate stock estimates via the perpetual inventory model.

These parametric issues aside, the presence of heterogeneity in our data samples does suggest that we should attempt to integrate additional information into our analysis of the depreciation process. The inclusion of macroeconomic, industry-level, and firm-specific covariates would strengthen the estimation framework.

Appendix 2.C: Depreciation Inputs for Capital Stock Estimation

Our experimental estimates of capital stock are based on constant (age-invariant) rates of depreciation that correspond to different asset groupings. In all, summary rates of depreciation were generated for 19 different asset groups—13 for machinery and equipment assets and 6 for structures—that, taken together, comprise the non-residential portion of the capital stock. There are two major methodological issues that shape our econometric estimation of these summary rates: (1) the choice of aggregation technique that we have used when producing summary rates from individual assets, and (2) the inclusion/exclusion of certain zero prices when calculating these summary rates. We discuss these issues below.

2.C.1 Aggregating Asset Information to Produce Summary Depreciation Rates

Our exponential rates were generated via a "bottom-up" application of our MLS model. To create a summary rate for an asset group, we estimated separate rates of depreciation for the individual assets that make up the group, and then pooled this information (via taking a weighted average of asset lives) to arrive at the aggregate, or summary, depreciation rate. This technique was used to reduce heterogeneity bias and produces more efficient estimates.

2.C.2 Eliminating "Problem Zeros" from Asset Samples

Our econometric results for individual assets in Section 5 are based on used-asset samples that include both positive selling prices and discards, the latter yielding a zero-value for the survival ratio depicted in equation 7. In earlier presentations of this study, several experts on National Accounting expressed concern over the extent to which the presence of large numbers of discards (i.e., observations with zero prices) in our asset samples impacts the estimation of the capital stock. In principle, the inclusion of observations with zero-prices is critical to the estimation process because it alleviates the selection bias that would arises if depreciation rates were based solely on surviving assets. This said, there was some concern that a certain portion of these zero records may be spurious, and that this, in turn, would lead us to overestimate the depreciation rate.

To address this concern, we utilized generalized residual distributions to identify and eliminate (potentially) spurious zero-price observations. Our approach to generalized residuals is based on the technique developed by Lancaster (1985b) that was outlined in Appendix 2.B. The basic intuition behind our exercise is to make use of sample residuals to detect statistical differences between observations with zero prices and those with positive prices.

First, we computed the log of the generalized residuals from the full asset samples. (In doing so, we made use of some industrial detail, as the incidence of zero observations is correlated with industry membership). Next, these residuals were compared with results from the sub-samples generated from zero prices. Data from these sub-samples were eliminated unless differences between sub-samples were not statistically significant. Depreciation estimates were then based on the remaining observations. In the text on capital estimation in Section 2.6, we refer to this as the "reduced-sample" version of the MLS model.

2.C.3 Summary Rates of Depreciation from the Reduced-sample

Our method for generating depreciation rates from this reduced sample derives from a set of decision rules. Note that we applied these rules to individual assets prior to generating the aggregate asset groups.

First, we compared the MLS depreciation estimate from the full sample to those generated from the reduced sample derived from the elimination of potentially spurious zero-price observations. If these rates are similar, we selected the depreciation rate from the reduced-sample.

If, for a given asset, there existed significant differences between the full and reduced-sample econometric estimates, we then considered an *ex ante* (non-econometric) estimate based on the double-declining balance depreciation rate (i.e., a rate generated from recent survey information on the service life). This non-econometric *ex ante* rate was used in place of the econometric reduced-sample rate in cases where the former is less than latter. If these comparisons did not yield a clear choice of depreciation rate, then we selected the lowest depreciation estimate from among the three alternative methods—the MLS rate (full sample), the MLS rate (reduced sample) and the double-declining geometric rate. For individual assets with small numbers of observations, the double-declining rate was used. Last, a small number of adjustments were made to the final estimates.

Depreciation estimates for the capital stock exercise are reported below.

Table 2.C1 Depreciation Rates of Non-residential Assets

	Asset Group	MLS (Full sample)	MLS (Reduced sample with adjustments)	Geometric DBR = 2	Geometric DBR = 1.65
1	Office Furniture, Furnishings	0.34	0.33	0.33	0.27
2	Computers and Office Equipment	0.59	(0.51, 0.58)*	0.43	0.35
3	Household and Services Machinery and Equipment	0.23	0.14	0.22	0.18
4	Electrical Industrial Machinery and Equipment	0.23	0.19	0.10	0.08
5	Non-Electrical Industrial Machinery and Equipment	0.28	0.22	0.27	0.22
6	Industrial Containers	0.08	0.05	0.21	0.17
7	Conveyors and Industrial Trucks	0.32	0.18	0.18	0.14
8	Automobiles and Buses	0.24	0.20	0.66	0.54
9	Trucks (excluding industrial trucks) and Trailers	0.25	0.20	0.36	0.29
10	Locomotives, Ships, Boats and Major Replacement Parts	0.16	0.12	0.11	0.09
11	Aircraft, Aircraft Engines and Other Major Replacement Parts	0.06	0.06	0.11	0.09
12	Communication Equipment	0.27	0.20	0.17	0.14
13	Other Equipment	0.21	0.20	0.21	0.10
14	Non-Residential Building Construction	0.08	0.07	0.08	0.04
15	Road, Highway and Airport Runway Construction	0.16	0.10	0.14	0.06
16	Gas and Oil Facility Construction	0.20	0.08	0.06	0.03
17	Electric Power, Dams and Irrigation Construction	0.15	0.06	0.06	0.03
18	Railway and Telecommunications Construction	0.11	0.10	0.12	0.05
19	Other Engineering Construction	0.24	0.08	0.07	0.03

* Separate estimates are made for goods and service industries, respectively.

3

The Changing Composition of the Canadian Workforce and its Impact on Productivity Growth

Wulong Gu, Mustapha Kaci, Jean-Pierre Maynard and Mary-Anne Sillamaa

3.1 Introduction

A key indicator of a nation's economic performance that is closely watched by economic analysts is productivity growth. In the long run, productivity growth is seen to be a key determinant of living standards. As a result, governments have adopted many different policies to provide businesses and workers incentives to improve productivity and international competitiveness. These have included accelerated depreciation allowances, subsidies for R&D, and support for innovative management practices that increase productive efficiency.

Statistics Canada publishes two main measures that track the growth of productivity in the business sector: labour productivity and multifactor productivity. Labour productivity is defined as output per unit of labour. Multifactor productivity (MFP) is defined as output per unit of combined capital and labour.

Labour productivity is a partial measure as it takes into account only one input—labour. Multifactor productivity measures are broader in that they capture the efficiency with which both capital and labour are used to produce output.

Labour productivity can increase either because there is a general improvement in efficiency or the amount of capital per unit of labour increases. Because multifactor productivity measures take into account both changes in labour and capital, they come closer to measuring just the increases in efficiency—where efficiency is defined broadly to include changes in plant size, organizational change, technological change and externalities.[1]

While labour productivity is a less comprehensive measure than multifactor productivity, some analysts feel labour productivity is more accurately estimated. It requires only measures of the growth in labour input, which can be derived in a relatively straightforward fashion from survey data. It continues to be used extensively in tracking the performance of the economy. The improvement in labour productivity over time is closely related to increases in workers' wages.

On the other hand, multifactor productivity measures require estimates of both labour and capital. Capital growth estimates require investment data, estimates of depreciation rates and length of life of assets. The latter are inherently more difficult to measure.

[1] Some multifactor productivity estimates also attempt to isolate these various effects (see Baldwin et al, 2001, Chapter 8).

Regardless of these issues, both productivity measures are widely used to track changes in the economy and both require estimates of the growth in labour services that enter into the production process. Labour services can increase either because the number of hours worked increase or because the services of labour per hour worked increase, possibly because the labour force becomes more skilled and, therefore, more productive. In order to capture the latter effect, comprehensive measures of the growth in labour services need to be devised that take into account the relative productivity of different groups.

A commonly used measure of the growth in labour services that are applied to production is the rate of growth in total hours worked. Growth rates derived from this measure implicitly weight the growth in hours-worked of different categories of workers by the category's share of hours worked in the base period. Measures of the growth in the simple sum of total hours worked across all worker categories treats hours worked to be the same across different types of workers (the more educated versus the less educated, the more experienced versus the young, and men versus women). For example, when the simple sum of hours worked is used, an hour worked by a worker just out of school is considered to be equal to an hour worked by a worker with twenty years of experience.

An alternative measure of the growth in labour services recognizes the differences in workers' contributions to productivity and weights the growth in hours worked in different worker categories by their relative productivity. It is sometimes referred to as a quality-corrected measure of labour input.

The weights that are required for this exercise are generally derived from shares of total compensation accounted for by the category. The theory of the firm stipulates that, under certain conditions (the firm is a price-taker on labour markets and attempts to minimize its total costs), each category of labour will be hired up to the point where the cost of an additional hour of labour is just equal to the additional revenue that using this labour generates. In this case, the wage rate of the category will reflect its marginal productivity. This implies that, to get a measure of labour services that reflects differences in relative productivity, the individual hours of different quality can be weighted by the share of each type of labour in total labour compensation.

The differences in the growth of the weighted measure and the unweighted sum of hours worked across workers can be used to measure the effect of labour composition or labour quality on labour services growth. Labour quality or labour composition increases when hours worked by employees with high relatively wage rates (workers with more experience and education) increase faster than hours worked by employees with relatively low wage rates.

Taking account of changes in the composition of labour is important from several perspectives. First, it provides a measure of the contribution that increases in labour quality (due to increased shares of more educated and more experienced workers) make to production growth. Second, it has implications for growth accounting exercises that produce productivity estimates, where the growth in productivity is a residual derived from calculating the growth in output minus the growth of combined inputs.

Representing productivity as a 'Hicks-neutral' augmentation A_t of aggregate input, output can be written as:

$$Y_t = A_t F(K_t, L_t) . \tag{1}$$

Under the assumptions of competitive product and factor markets, and constant returns to scale, growth accounting gives the growth of output as the sum of the share-weighted growth of inputs and growth in multifactor productivity. Equivalently, multifactor productivity growth is the difference between the growth in output (Y) and combined inputs—labour (L) and capital (K).

$$MFP = \Delta \ln A_t = \Delta \ln Y_t - \bar{s}_{K,t} \Delta \ln K_t - \bar{s}_{L,t} \Delta \ln L_t , \tag{2}$$

where $\bar{s}_{K,t}$ is capital's average share of nominal value-added, $\bar{s}_{L,t}$ is labour's average share of nominal value-added, $\bar{s}_{K,t} + \bar{s}_{L,t} = 1$, the augmentation factor $\Delta \ln A_t$ captures multifactor productivity and Δ refers to a first difference.

Now consider two measures of labour change—the quality corrected measure ($\Delta \ln L_t$) and the measure that is not corrected ($\Delta \ln H_t$). If the hours worked in those worker categories whose wage share is above their hours share (whose relative wages rates are higher) grow faster than the hours worked in the lower wage categories, the quality adjusted labour services input ($\Delta \ln L_t$) will grow more quickly than a simple sum of the hours of all categories of workers ($\Delta \ln H_t$). In this case, using the quality adjusted measure of labour services to measure multifactor productivity growth in equation (2) will yield a lower estimate of productivity growth than using the simple sum of hours worked. Labour productivity growth that is measured as the growth of output per unweighted hour will partially reflect the contribution from labour compositional changes. Using the quality adjusted labour growth measure purges the productivity growth estimate of the effect of increasing skills by attributing part of the growth to this augmentation of skills.

Normally, changes in labour composition are minor in the short run, since the proportion of the workforce with a particular characteristic grows or declines slowly over time. Thus, short-run studies of changes in productivity that use unweighted estimates of the growth in labour services will not create a large distortion in the productivity estimates. But, in the long run, changing labour composition is more likely to occur. For example, over the last thirty years, there has been a dramatic change in the proportion of the labour force that is more educated and more experienced. Therefore, studies that examine long-run changes in productivity need to consider compositional changes in labour services.

Of course, the procedure for deriving a measure that weights the different categories by their relative productivity depends on the assumption that wage differentials broadly reflect differences in marginal productivity. While there will be disagreements about the categories where this is true, operating on the opposite assumption (that there are no differences across worker categories) is equally problematic. The choice facing statisticians is between a measure of labour services input like the sum of hours-worked that is

less desirable conceptually, but possibly more accurately estimated, or a measure that is more sound in theory (the weighted sum of hours worked) but less precisely estimated.

In this chapter, we outline the methodology used to derive indices of labour services that account for differences in productivity across worker categories and then investigate the effect on standard measures of productivity when the alternate measure is used. The rest of the study is organized as follows. Section 3.2 provides an overview of the methodology that is used for measuring labour compositional change. Section 3.3 describes in more detail a labour composition index that was estimated from Canadian data with a method based on that of Jorgenson, Gollop and Fraumeni[2] (1987). Section 3.4 describes a labour composition index that was estimated from Canadian data using a Bureau of Labor Statistics (BLS) type (1993) method. The section also explains the differences in the two estimates. Section 3.5 compares U.S. and Canadian results for both methods. Section 3.6 examines the implications of labour compositional changes for labour productivity growth. Section 3.7 concludes the chapter.

3.2 Methods for Measuring Growth in Labour Services[3]

In this section, we present the index that will be used to measure the growth of labour services and changes therein that are due to changing labour composition. We then discuss two alternative approaches to estimating the Tornqvist index of labour services. The first approach is that proposed by JGF and more recently used by Ho and Jorgenson (1998). The second is based on the BLS approach.

3.2.1 Tornqvist Index of Growth in Labour and Changes in Labour Composition

The construction of the growth in labour services and changes in labour composition begins with a production function that relates output to labour and capital services:

$$Y_t = A_t F(K_t, L_t), \tag{3}$$

where Y_t is output (or value-added) in period t, L_t the index of labour services, K_t the index of capital services, and A_t is Hicks-neutral augmentation of aggregate input.

We assume that there are many types of labour inputs and capital inputs. The indices of labour and capital services are aggregated from the various types of labour and capital inputs. Labour services input can be expressed as a function of the hours worked of the various types of workers:

$$L_t = f(h_{lt}, \ldots, \mathrm{h}_{\mathrm{lt},} \ldots h_{Ct}), \tag{4}$$

where h_{lt}, $l = 1, \ldots, C$ is the number of hours worked by workers of type l. Similarly, capital services can be written as a function of the various types of capital inputs.

[2] In the rest of this report, Jorgenson, Gollop and Fraumeni will be referred to as JGF.

[3] This section follows closely the section 2 of Ho and Jorgenson (1998) and the section 1 of Chinloy (1980).

Assuming that labour markets are competitive and production is characterized by constant returns to scale, we can write changes in labour services input as the weighted sum of changes in hours worked by the various types of workers:

$$\frac{\partial \ln L_t}{\partial t} = \sum_{l=1}^{C} \upsilon_{lt} \frac{\partial \ln h_{lt}}{\partial t} , \tag{5}$$

with

$$\upsilon_{lt} = \frac{\partial \ln f}{\partial \ln h_{lt}} = \frac{w_{lt} h_{lt}}{\sum_{l=1}^{C} w_{lt} h_{lt}} , \tag{6}$$

where υ_{lt} is the share of labour compensation attributed to the workers of type l, and w_{lt} is the hourly compensation rate of workers of type l. As workers' compensation rates equal their value of marginal product in competitive labour markets, weighting the hours of various types of workers by their compensation rates accounts for the difference in productive contribution across the types of workers.

The total number of hours worked is defined as the unweighted sum of hours worked across workers of various types:

$$H_t = \sum_{l=1}^{C} h_{lt} . \tag{7}$$

Let $\beta_{lt} = \frac{h_{lt}}{H_t}$ denote the share of worker type l in the total number of hours worked. The changes in the unweighted sum of hours worked can be written as:

$$\frac{\partial \ln H_t}{\partial t} = \sum_{l=1}^{C} \beta_{lt} \frac{\partial \ln h_{lt}}{\partial t} . \tag{8}$$

The difference between the changes in weighted sum and unweighted sum of hours worked is referred to herein as the compositional effect. Labour composition LC_t is defined as the ratio of labour services to hours worked:

$$LC_t = \frac{L_t}{H_t} . \tag{9}$$

Using the equations for changes in labour services and hours worked, we can write the changes in labour composition as:

$$\frac{\partial \ln LC_t}{\partial t} = \sum_{l=1}^{C} (\upsilon_{lt} - \beta_{lt}) \frac{\partial \ln h_{lt}}{\partial t} . \tag{10}$$

Increases in the hours of a worker contribute positively to labour composition if the worker receives relatively high wage rates. Increases in the hours of a worker contribute negatively to labour composition if the worker receives relatively low wage rates. Whether the weighted sum of hours worked grows more quickly than the unweighted sum depends upon whether the wage share of the category is larger than the hours share *and* whether the rate of growth in hours is above the mean—that is whether the larger weights $(\upsilon_{lt} - \beta_{lt})$ in equation (10) are applied to faster growing categories.

These equations express changes in a continuous form. Implementation of equations (5) and (10) for estimating labour services input and labour composition over discrete time periods requires the specification of an aggregation function of labour services input. When the aggregation function is of a translog form, we obtain a Tornqvist index of labour services input and labour composition. The Tornqvist index of labour services input can be written as:

$$\Delta \ln L_t = \sum_{l=1}^{C} \bar{\upsilon}_{lt} \Delta \ln h_{lt} . \tag{11}$$

Where Δ denotes changes between periods $t-1$ and t, and the weights for aggregating hours of the various types of workers are the average compensation share of the worker type:

$$\bar{\upsilon}_{lt} = \frac{1}{2}\left(\upsilon_{lt} + \upsilon_{l(t-1)}\right). \tag{12}$$

The growth of hours worked, defined previously in continuous form, can be written in discrete time more simply as:

$$\Delta \ln H_t = \Delta \ln \sum_{l=1}^{C} h_{lt} . \tag{13}$$

It follows directly from equations (11) and (13) that the logarithmic change in labour composition can be represented by the following formula:

$$\Delta \ln LC_t = \Delta \ln L_t - \Delta \ln H_t = \sum_{l=1}^{C} \bar{\upsilon}_l \Delta \ln h_{lt} - \Delta \ln \sum_{l=1}^{C} h_{lt} . \tag{14}$$

The labour composition indices are constructed from the antilogarithms of this differential. The growth of labour composition is the difference between the weighted and unweighted growth rates of hours worked. Labour quality is said to increase when the labour services input grows faster than total hours worked, when the composition effect is positive. This will occur when the proportion of workers with relatively high earnings (better-educated, more experienced workers) increases. In contrast, labour quality declines when the proportion of such workers decreases, when the composition effect is negative.

To identify the contribution to labour input that is made by shifts in the proportion of workers with particular characteristics such as gender, age, education and employment class separately, we construct the partial indices of labour services input corresponding to these worker characteristics based on a decomposition analysis. For this purpose, we denote $\{H_{saec}\}$ the components of hours worked, classified by gender s, age a, education e, and employment class c. We also consider shares of these components in the value of labour compensation $\{v_{saec}\}$. A partial index of labour input corresponding to, for example, gender, is defined as follows:

$$\Delta \ln L^{gender} = \sum_s \bar{v}_s \Delta \ln h_s \,, \tag{15}$$

$$= \sum_s \bar{v}_s \Delta \ln \left(\sum_a \sum_e \sum_c h_{saec} \right),$$

where:

$$\bar{v}_s = \frac{1}{2}\left[v_s(t) + v_s(t-1) \right],$$

$$v_s = \sum_a \sum_e \sum_c v_{saec} \,.$$

The partial index of labour services growth corresponding to gender captures substitution between the two sexes alone. Similarly, the partial input index for age, education or employment class measures substitution between age groups, educational attainment levels or employment classes.

As in most decomposition analyses, the sum of the individual components do not add perfectly to the total, because the individual components do not allow for substitution across categories.

The growth rate of the partial index of labour composition is the difference between the growth rates of partial labour services input index and hours worked.

3.2.2 Two Empirical Approaches to Estimating Growth in Labour Services and the Effect of Changing Labour Composition

In practice, there have been two related but different approaches used to estimate the growth in quality-adjusted labour services by weighting the growth in hours of work across various types of workers by their wage shares.

First, JGF (1987) have constructed labour services input indices for 51 industries and for the American economy as a whole for the 1947-1979 period. Their measure takes into account the changes that occur in labour composition by considering differences in growth rates in hours worked across categories that are defined by age, gender, level of education, class of worker and occupation. Average wage rates and income shares are calculated for workers grouped into strata defined by these characteristics.

Second, the U.S. Bureau of Labor Statistics (BLS, 1993) has developed an alternative measure of labour input for the business sector. The measure represents a rising average level of worker skills as measured by education and experience for each gender. The BLS has used statistical regression analysis to isolate the impact of education and experience on wage rates. They incorporate in their analysis socio-demographic factors such as level of education, experience, birth rate and female labour force participation.[4] They then use the predicted wage rate from their regression to calculate wage shares. Since 1993, the official BLS multifactor productivity measure for the business sector (but not for individual industries) has been adjusted for changes in labour composition.

Both the JGF and the BLS approaches begin with the construction of hours worked and earning weights by strata that are defined by particular worker characteristics. The main differences between the two approaches relate to the enumeration of possible worker types and the manner of the construction of earning weights.[5]

Worker types. JGF uses five characteristics of workers: education, age, gender, employment class (paid vs self-employed), and occupation. Ho and Jorgenson (1998) drop the occupation characteristic in their extension of JGF (1987), since JGF found that the occupation mix had little effect on the labour composition index once the other four worker characteristics were taken into account.

On the other hand, the BLS uses three worker characteristics: education, work experience and gender. The BLS does not separate paid and self-employed workers. The education variable in the BLS approach is defined for seven schooling groups, whereas the levels of schooling considered by JGF consist of five groups.

JGF uses a worker's age variable to measure the level of on-the-job training and productivity differences between workers. The BLS replaces this age variable in the JGF approach with work experience—a variable that is imputed from age. Work experience for men is found to be reasonably well predicted by the commonly used potential experience (age minus years of schooling minus 6). However, potential experience was found to be a poor proxy for actual experience in women, due to low rates of labour force participation in the early post-war period and during childbearing years.

The BLS chooses to estimate experience equations for men and women using actual work histories from linked Current Population Surveys (CPS)/ Social Security Administration (SSA) data set for 1973. The file links individual records from the SSA files and the March 1973 CPS. Explanatory variables in the experience equation for men include potential experience, years of schooling, and interactions between potential experience and years of schooling. For women, explanatory variables include the variables in the men's experience equation plus marital status and the number of children ever born. The fitted experience equations from the 1973 CPS/SSA data set are then used to estimate work experience for other years.

Earning weights. Both the JGF and the BLS approaches make use of household surveys and the population census to estimate relative earnings of the various types of workers. JGF earning weights are estimated as survey sample averages for all persons of a given characteristic. In contrast, the BLS earning weights are based on wage models estimated from the Population Censuses for 1950 and 1960 and annually from the CPS

[4] For a general survey of the literature on the subject, see Dean and Harper (1998).

[5] For a comprehensive discussion of similarities and differences between the two approaches, see Appendix A and F of BLS (1993).

beginning in 1968. Weights for other years are derived from linear interpolation of the estimated parameters.

The BLS argues that the difference in the simple average of wage rates between two types of workers that are used in the JGF approach reflects not only the characteristics identifying the groups (such as experience and education) but that it also reflects other characteristics that are not used to identify groups that are highly correlated with these characteristics. For example, wage differentials across education classes may be the result of parental background rather than of educational training. As such a simple wage differential between two educational classes overstates the effects of the differences in qualifications. This argument is equivalent to the argument that the JGF approach is using a wage function that only considers education and is misspecified.

The wage equation approach that is used by the BLS to predict wages for a particular characteristic like education tries to isolate only the wage differentials associated with work experience and educational attainment; and the resulting index of labour composition based on estimated wages from the multivariate analysis attempts to provide a more precise estimate of the marginal contribution of experience and education to labour services growth.

Canada: In Canada, the existing measure of labour services input for the business sector that is used in Statistics Canada's productivity program is constructed by aggregating the hours of work across industries by their wage bill shares. This measure takes into account the differences in worker characteristics across industries. A number of recent papers (Coulombe, 2000; Diewert, 2000) have suggested that more detailed official estimates of changing labour compositional changes are needed. This chapter provides these estimates.

There are several precursors to this exercise. Dougherty (1992) devised labour services input indices for Canada and the other G7 countries for the 1960-1989 period. These labour services input indices are aggregated from workers broken down by level of education and employment category. Jorgenson and Yip (1998) experimented with extending the analysis to cover the 1960-1995 period, but did not use as comprehensive a set of source data as are used in this chapter. Gu and Maynard (2001) experimented with more comprehensive data and the JGF approach to construct a preliminary measure of labour services input for the business sector and individual industries from1961-1995.

In this chapter, we finalize the preliminary estimates of Gu and Maynard (2001) and estimate labour services input indices for a more recent period. We also examine the robustness of labour services input estimates by employing an alternate method—a BLS-type estimator. The BLS (1993) reports that there is a considerable difference between the U.S. estimates that are yielded by the BLS approach and those yielded by the Jorgenson method. Therefore, we examine how sensitive measures of the growth in Canadian labour services are to the two methods that are used in constructing the U.S. labour services input measures.

Table 3.1 Worker Classifications

Labour Characteristics	Number of Categories	Description
Gender	2	Female; male
Age Group	7	15-17; 18-24; 25-34; 35-44; 45-54; 55-64; 65+
Education	4	Primary; secondary; post secondary; university
Class of Workers	2	Paid workers; other categories

3.3. Estimating Canadian Labour Compositional Change with the JGF Method

In this section we describe the Canadian data that are used for the analysis and present the indices of labour composition for the business sector and individual industries using the JGF method.

3.3.1 Constructing the Labour Composition Index

To estimate indices of labour services input and labour composition, we disaggregate workers by gender, seven age groups, four education levels and two employment categories for a total of 112 types of worker (Table 3.1). Two sets of data are used to construct consistent estimates of hours worked and labour compensation for each of the characteristics considered:

- data from Statistics Canada's productivity database by industry and employment category (paid workers, self-employed workers and unpaid family workers) for every year since 1961; and

- data by industry, class of worker, age, gender and level of schooling that was constructed from the Census of Population and various household surveys (Labour Force Survey (LFS); Survey of Consumer Finances (SCF); and Survey of Labour and Income Dynamics (SLID)).

Data on hours worked and earnings by industry and employment categories from Statistics Canada's productivity database. The concept of hours worked for the Statistics Canada's productivity program is essentially the one recommended in the 1993 System of National Accounts (SNA) manual. Hours worked are derived from the total number of hours that a person spends at work, whether they are paid hours or not.[6] In general, it encompasses both regular hours and overtime, including breaks, travel time, on-the-job training time and time lost because of temporary stoppages during which employees remain at their posts. Hours worked do not include time lost due to strikes or lockouts, annual vacations, statutory holidays, sick leave, maternity leave or leave for personal responsibilities.

Estimates of hours-worked are broken down into three main employment categories: paid employment, self-employment and unpaid family employment. The latter occurs mostly in industries with significant numbers of family businesses (primarily agriculture and retail trade).

For productivity calculations at Statistics Canada, the number of hours worked is obtained by multiplying the number of jobs by the average annual hours worked. In general, estimates of the number of paid jobs are based on combined employment data from household surveys (LFS; SLID; and censuses) and business surveys (Survey of

[6] Those who are not at work but are paid are included in the total.

Employment, Payrolls and Hours, Annual Survey of Manufactures, Census of Mines, etc.). Data for other employment categories are taken directly from the LFS. Except for some mining and manufacturing industries, all data on average hours worked also come from the LFS. Data on hours worked by sector and by industry are consistent with the System of National Accounts and are adjusted for known statistical discontinuities.

Labour compensation as defined for the productivity program includes all payments in cash or in kind that Canadian producers make to workers in return for their services. It includes labour income such as wages and salaries (including bonuses, tips, taxable allowances and backpay), supplementary income of paid workers (various employer contributions) and the implicit labour income of self-employed workers.

The hourly earnings of workers are given by the quotient of total compensation paid for all jobs divided by total hours worked.

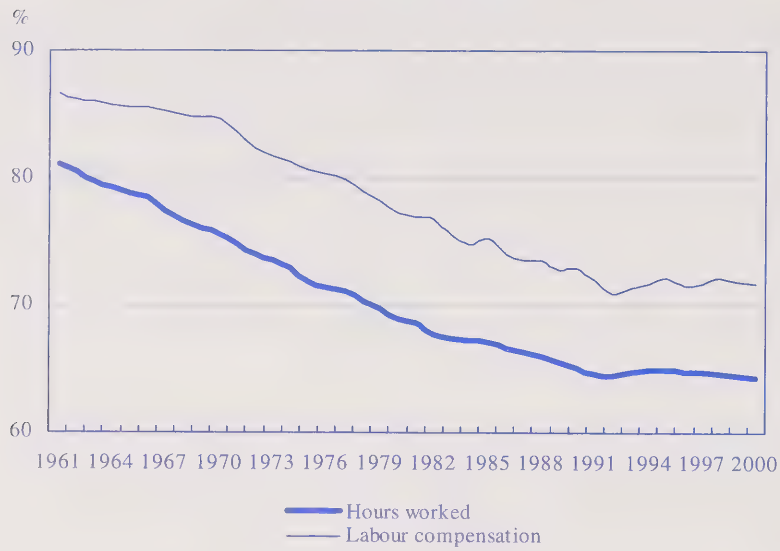
Income data for all paid employment originate directly from the estimates of employment income produced by Income and Expenditure Accounts. In the case of self-employed workers, combined labour income is obtained by imputation, using the assumption that the value of an hour worked by a self-employed worker is equal to the value of an hour worked by a paid worker (at the average rate) in the same industry. The same imputation approach is used to produce data for unpaid family workers. In addition, employment income for certain professionals (physicians, lawyers, dentists, accountants and engineers) is derived from income tax statistics (Revenue Canada, Catalogue No. RV 44).

Data on hours worked and earnings by industry, gender, age group, education and employment categories from household surveys and the population census. Data from the 1961, 1971, 1981, 1986, 1991 and 1996 censuses of population were used to construct hours worked and labour compensation for the census reference years (1961, 1970, 1980, 1985, 1990, 1995). For the non-census years prior to 1976, data on hours worked and earnings are estimated from a linear interpolation of the data from two adjacent Censuses. After 1976, the hours data derived from a linear interpolation of the two adjacent Censuses are reconciled with the data on hours worked by worker characteristics in the aggregate business sector from LFS. The hourly earnings data derived from a linear interpolation of the two adjacent Censuses are adjusted to the hourly earning estimates from the two household surveys: SCF over the 1976-1993 period; and SLID after 1993.

In January 1990, the LFS revised the questions related to educational attainments of the respondents. From 1976 to 1989, post-secondary education was limited to education that normally requires high-school graduation. After 1990, post-secondary education included any education that could be counted towards a degree, certificate or diploma from educational institutions. The change caused a reallocation of respondents from secondary to post-secondary education. To ensure the data is consistent over time, we chose not to use the pre-1990 data on hours worked by education from the LFS. The data on hours worked by education prior to 1990 was calculated instead as a linear interpolation of the two adjacent Censuses.

Since 1961 Census data are not available in electronic form, the iterative proportional fitting method (see JGF (1987)) was used to estimate data on hours worked and hourly earnings by industry, gender, age group, education and employment classes (see Gu and Maynard, 2001 for details).

Figure 3.1 Share of Labour Compensation and Hours by Male Workers in the Business Sector



Combining the data from household surveys and the population census with the estimates of the productivity program. The data on hours worked and earnings that are constructed from household surveys and the Census of Population are reconciled with the annual benchmark data used in Statistics Canada's productivity program. The two sets of data were reconciled using their common variables (industry and class of worker category). Constructing the hours-worked data required reconciliation since number of hours worked derived from the Census refers to the census week while earnings and number of weeks worked refer to the previous year. Hours worked are computed by multiplying the average hours worked during the census reference week by the number of weeks worked the previous year.

Once the data on annual hours worked and hourly earnings by industry, age group, gender, level of education and employment category were collected, the indices of labour composition were constructed for the business sector over the 1961-2000 period.

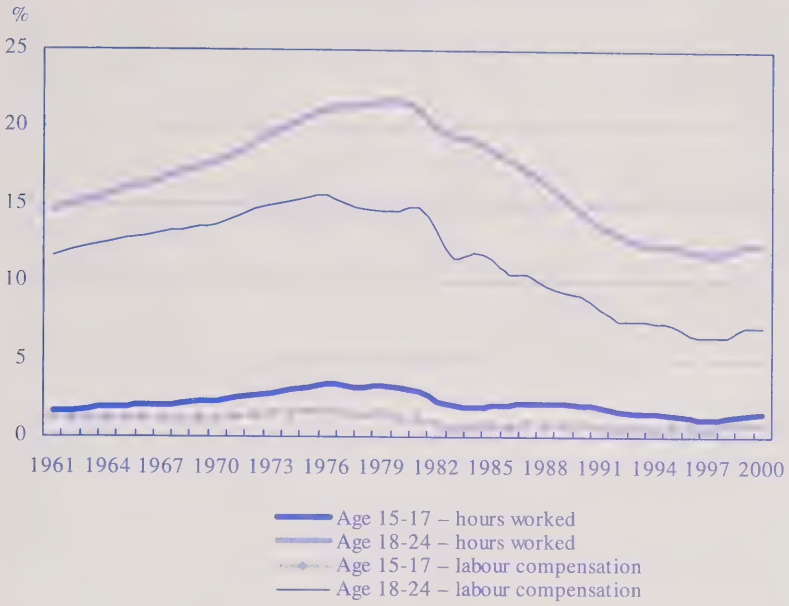
3.3.2 Trends in the Composition of Hours Worked in the Business Sector

Before examining the effect of considering all factors (education, age, gender, and class of worker) together, we first present the trend in the shares and relative wage rates of each factor taken by itself.

The contribution of the change in the composition of hours worked to labour input can be either positive or negative for each category—gender, age, level of education and employment category. In this section, we present summary data that will reveal the effect of the changing composition of the labour force on our estimate of the growth in labour services.

In what follows, we examine changes in the relative importance of a type of workers over the time period using both the wage share and the hours share of each type of worker. If the wage share is greater than the hours share of a particular category, then the growth rate of labour services that takes into account wage differences will weight that category (i.e. educated workers) more heavily than the estimate that just uses the straight sum of hours worked. And if that category (i.e. educated workers) has higher

Figure 3.2 Share of Labour Compensation and HoursWorked by Age Group in the Business Sector: Ages 15-17 and 18-24



than average growth (as evidenced by a growth in the share of hours-worked of that category), then the wage-weighted rate of growth of labour services will have a higher rate of growth than the rate of growth that is derived from the simple sum of hours-worked, which implicitly weights each category's rate of growth by its share of hours-worked. If the category has a lower than average growth rate, the opposite will occur.

3.3.2.1 Gender

Figure 3.1 shows the change in the share of hours worked by male workers in the business sector between 1961 and 2000. Over that period, the share of hours worked by men declined from 81.0% in 1961 to 64.3% in 2000. The male worker on average receives a higher wage than does a female worker and consequently the wage share of male workers is higher than their hours share. The combination of a lower rate of growth for hours worked by male workers and the higher wage share means that the growth rate in the weighted labour input that takes into the gender composition of the labour force will be lower than the unweighted estimate. The feminization of the labour force will have a slight dampening effect on labour composition growth.

3.3.2.2 Age Group

Hours worked by age group in the Canadian business sector have changed substantially over the last forty years (Figures 3.2, 3.3, and 3.4). The 1971-1980 period was characterized by the entry of younger workers—the post-war baby-boomers to the workforce. Since age is a proxy for experience, this period was marked by a general decrease in the average experience of the labour force.

The share of hours worked by the 15-17 and 18-24 age groups rose steadily between 1961 and 1980. There was also a relatively large increase in the size of the 25-34 age group in the 1970s as the baby boomers entered the workforce. On the other hand, between 1961 and 1980, the share of hours worked for the 35-44 and 45-54 age groups declined.

Figure 3.3 Share of Labour Compensation and Hours Worked by Age Group in the Business Sector: Ages 25-34 and 35-44

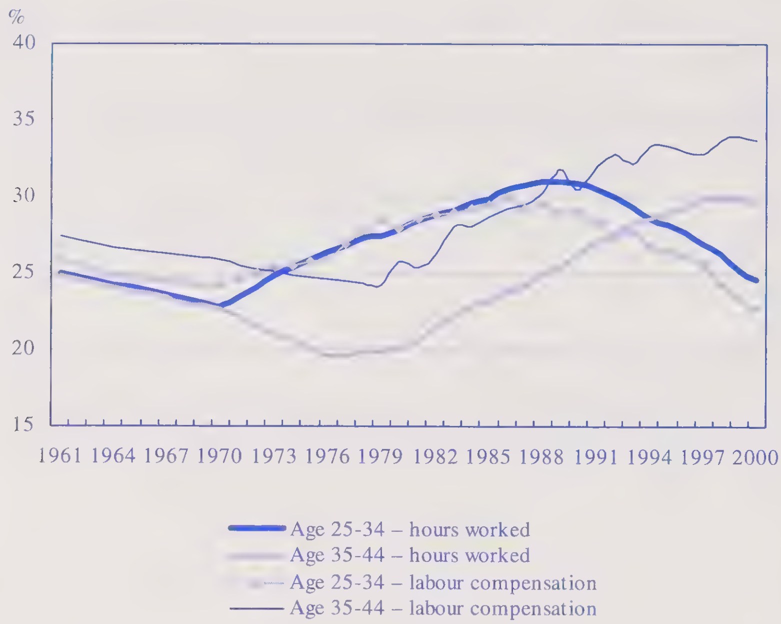
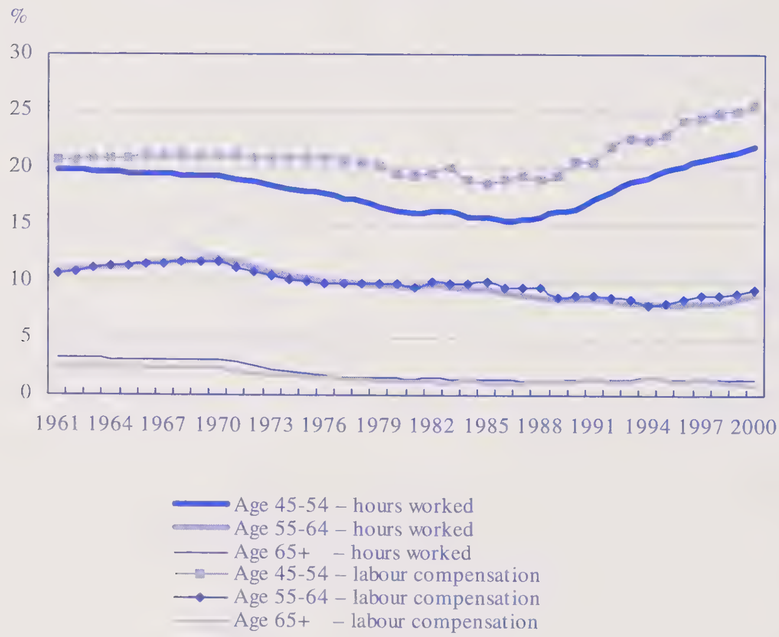


Figure 3.4 Share of Labour Compensation and Hours Worked by Age Group in the Business Sector: Ages 45-54, 55-64 and 65+



The trend towards a less-experienced workforce reversed itself in the early 1980s, when the baby-boomers entered the 35-44 age group. Between 1980 and 2000, the share of hours worked for the 15-17 age group dropped from 3.1% to 1.5%, and for the 18-24 group from 21.7% to 12.4%. Over the same period, the share of hours worked for the 35-44 group increased from 20.1% to 29.6%, and for the 45-54 group from 16.3% to 21.9%.

Relative wage rates differ across these groups, with the young receiving a lower than average wage and the older more experienced worker receiving higher wages. Throughout the period, the share of compensation going to the 15 to 24 year-old group is constantly below that of their hours worked. On the other hand, the share of compensation going to the 35 to 44 year-old group was above their hours worked and the difference increased before the early 1980s and showed slight declines afterwards. The same is the case for the 45 to 54 year-old group, though here the differential increased before the early 1980s and showed little changes thereafter.

Together the lower wage share of younger workers and their higher rates of hours growth in the earlier period means that a labour measure that weights hours-worked by relative wage share will grow less quickly in the period from 1961-1980. On the other hand, it will grow more quickly subsequently. We should therefore expect the effect of age, a proxy for experience, to have changed over time. It should be negative in the early period and increasing later.

3.3.2.3 Education

Levels of education have risen steadily since the 1960s. Figures 3.5 and 3.6 show that the share of hours worked by those with the two highest levels of educational attainment have increased over time. The share of hours worked by workers with a post-secondary education rose from 2.9% in 1961 to 42.8% in 2000. Over the same period, the share held by workers with a university education climbed from 3.3% to 15.5%.

Figures 3.5 and 3.6 also show that the share of wages for these two groups is higher than their share of hours worked. Thus, taking into account labour composition will give a higher weight to the two categories that are growing most rapidly. As such, the compositional effect due to education should be positive.

It is also useful to note that the relative importance of these weights has changed over time. In the period up to 1981, the wage share of the two groups with post-secondary or university education was considerably above their hours-worked share. While this continues for the university educated after 1981, this is no longer the case for the post-secondary group in this period. This will reduce the compositional effect due to improvements in education later in the period.

3.3.2.4 Employment Category

The last category considered is paid versus unpaid workers. As in Ho and Jorgenson (1998), we grouped unpaid family workers and self-employed workers together in the same employment category.

Figure 3.7 shows that the share of total hours worked by paid workers climbed steadily between 1961 and the late 1980s. The trend was particularly strong before 1975. After the late 1980s, the share of paid workers declined, while the share of workers other than paid workers increased.

Figure 3.5 Share of Labour Compensation and Hours Worked by Education Attainment in the Business Sector: Primary and Secondary

Figure 3.6 Share of Labour Compensation and Hours Worked by Education Attainment in the Business Sector: Post-secondary and University

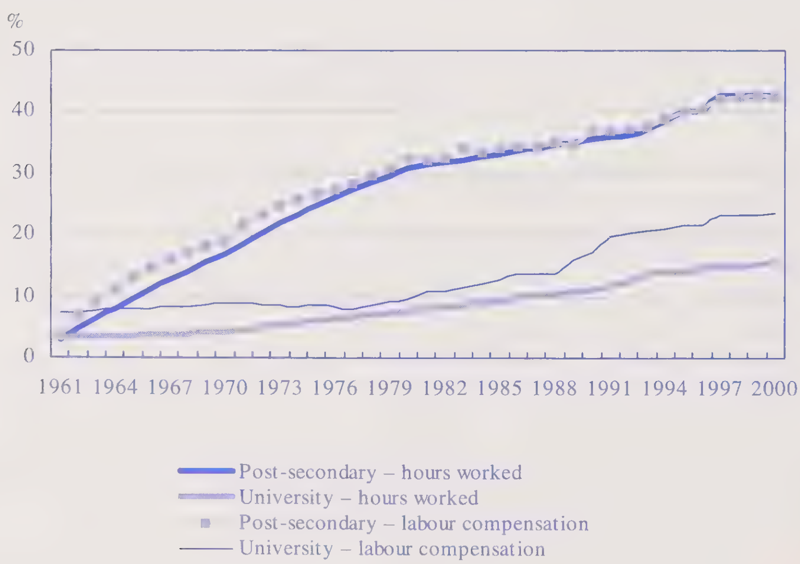
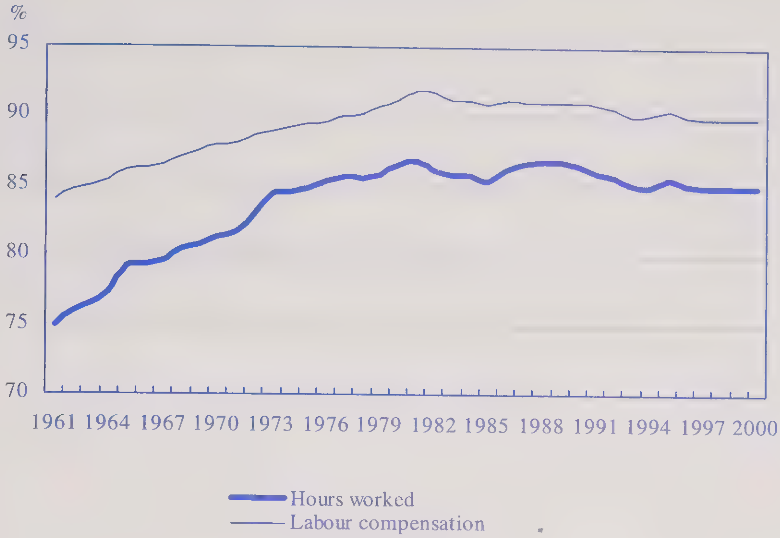


Figure 3.7 Share of Labour Compensation and Hours Worked by Paid Workers in the Business Sector



The share of wages going to paid workers is slightly higher than their share of hours worked. This means that higher growth in paid workers in the period prior to the 1990s will make a slight contribution to the growth in the composition effect. On the other hand, it will slow the growth in the composition effect in the 1990s.

3.3.3 Trends in the Growth of Labour Composition in the Business Sector

The results of applying Jorgenson's methodology, that is, of estimating the annual growth rates of labour input, hours worked and labour composition in the business sector over the 1961-2000 period and selected intervals within that period, are summarized in Table 3.2. The table contains the rate of growth of unweighted hours worked—what is normally used in productivity studies—and the average weighted growth rate. The difference is the effect of compositional change. We also include the marginal effect of each factor.

With the changing composition taken into account, the growth rates of labour input are higher than the growth in the straight sum of hours worked. The average annual growth rates in weighted hours worked were 2.75%, 2.01%, 2.63%, 1.17% and 3.48% over the periods 1961-1973, 1973-1979, 1979-1988, 1988-1995 and 1995-2000, while the growth rates derived using the straight sum of hours worked were 1.90%, 1.92%, 2.04%, 0.27% and 3.05%, respectively.

The increases due to increasing quality or changes in labour composition were substantial: they averaged 0.62% a year for the entire period, but fluctuated considerably from period to period: 0.84% for 1961-1973, 0.09% for 1973-1979, 0.59% for 1979-1988, 0.89% for 1988-1995, and 0.43% for 1995-2000. The increase in labour composition growth was slowest in the period that coincided with the entry of baby-boomers and the rapid increase of women in the workforce.

Figure 3.8 Indices of Labour Input, Hours Worked and Labour Composition in the Business Sector

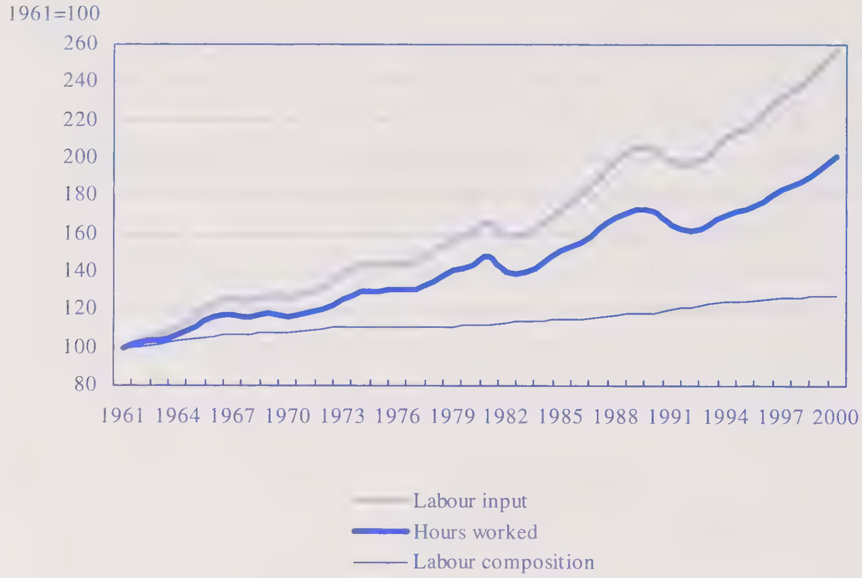


Figure 3.9 Partial Indices of Labour Composition in the Business Sector

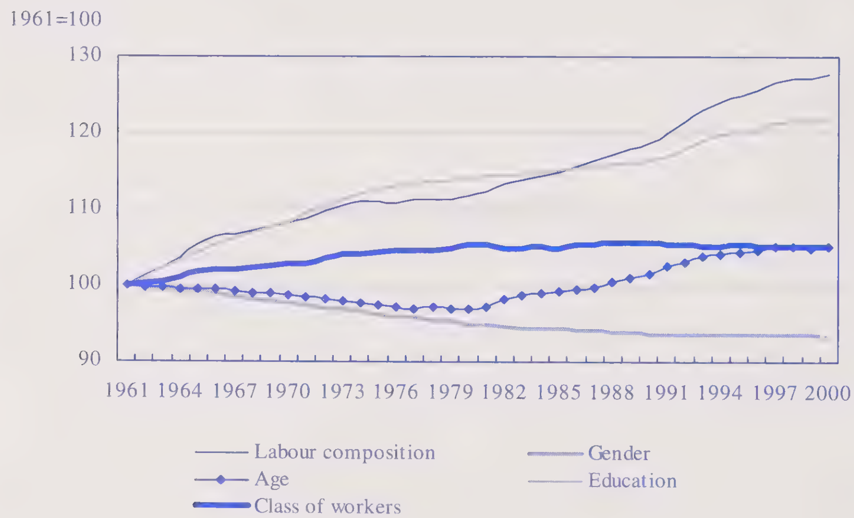


Table 3.2 Annual Changes in Labour Input, Hours and Labour Composition for Business Sector (Percent)

	1961-2000	Subperiods				
		1961-1973	1973-1979	1979-1988	1988-1995	1995-2000
Labour Input	2.42	2.75	2.01	2.63	1.17	3.48
Hours	1.79	1.90	1.92	2.04	0.27	3.05
Labour Composition	0.62	0.84	0.09	0.59	0.89	0.43
Partial Indices of Labour Composition						
Gender	-0.17	-0.27	-0.26	-0.16	-0.06	-0.04
Age	0.13	-0.17	-0.19	0.40	0.54	0.14
Education	0.51	0.89	0.36	0.21	0.51	0.30
Class of Worker	0.13	0.34	0.11	0.09	-0.04	-0.05

Note: Changes in labour composition plus changes in hours worked may not add to changes in labour input due to rounding.

The movement of the indices of labour input, hours worked and labour composition in the business sector between 1961 and 2000 are plotted in Figure 3.8. Over the entire study period, labour composition accounted for an average of 25.6% of labour input (30.5% for 1961-1973, 4.5% for 1973-1979, 22.4% for 1979-1988, 76.1% for 1988-1995, and 12.4% for 1995-2000). The pace of the growth in labour composition increased in the 1988-1995 period to a level three times as high as the growth rate of hours worked (0.89% compared with 0.27%).

The relative impact of education, age, gender, and class of worker is presented in the bottom half of Table 3.2 and in Figure 3.9. Rising education attainment is the main factor in making labour composition growth positive. It accounts for most of the impact of changing labour composition in each period.

The second most important factor is age of worker—a proxy for experience. Over the whole period, its average effect is not large; but it had a negative impact in the 1960s and 1970s when the growth in younger workers was faster than for more experienced workers. There was a positive impact on labour composition after the 1980s from changes in age composition when the reverse was true.

The changing male/female composition had a dampening effect on labour composition. But the effect was not large.

Finally, movement away from self-employment to paid employment generally had a positive effect on the growth of labour. However, the impact of this variable was largest in the 1960s. In more recent years, with the growth in self-employment, there has been a slight negative effect resulting from the shift that has taken place from paid and self-employed status.

We have also calculated the index of labour composition for the individual industries at the L-level industry aggregation, as shown in Appendix Table 3.A1. Over the 1961-1997 period, the growth in labour composition was positive in 132 of the 147 industries of the Canadian business sector. Annual growth of labour composition over the period ranges from -1.32% to +1.61%.

Table 3.3 Worker Classifications

Labour Characteristics	Number of Categories	Description
Gender	2	Female; male
Age	60	Individual years 15-85; all others excluded
Education	4	Any primary; any secondary; any post secondary excluding university graduates; university graduates

3.4. Estimating Canadian Labour Compositional Change with a BLS-style Method

This section examines the sensitivity of the labour compositional change to an alternate estimation technique—that of the Bureau of Labor Statistics. The BLS (1993) reports substantial differences in the final estimates that are produced by their method and that of JGH (1987).

3.4.1 Constructing the Labour Composition Index

Central to the BLS approach are estimated wage functions that are used to estimate wage shares. These are derived for Canada from data on hours worked, hourly earnings, and the characteristics for individuals taken from microdata that comes from the Censuses of Population for 1971, 1981, 1986, 1991, and 1996. To be comparable to U.S. BLS results, only workers in the private business sector were included. For the regression, workers were disaggregated by gender, age, and four education levels for a total of 480 types of worker (Table 3.3).

Estimating hours worked. Since annual hours worked is not provided directly in the Census, it was calculated as the number of weeks worked by the individual at their primary job in the year preceding the Census times the number of hours worked during the Census week.[7] A limit of 4,500 hours per year was imposed on the calculation. People with zero calculated hours were eliminated.

Estimating hourly earnings. Paid employees and incorporated self-employed individuals were segregated into two groups for the purpose of estimating hourly earnings. The average hourly earnings (average wage rate) for each category of these workers was calculated as the quotient of total annual compensation paid the workers over the estimate of total annual hours worked.

The log wage rate was then regressed against a linear specification consisting of age, age squared, education level dummy variables, and other personal characteristic dummies that could be defined from the Census databases. While the BLS makes use of an elaborate procedure to predict experience from age, they also report that making use of age alone produces almost the same results. Therefore, we adopted the latter approach. Separate regressions were run for men and women. Detailed regression results are presented in Appendix Tables 3.A2 and 3.A3.

The results for the five different years show several interesting trends. First the coefficient on age gradually increases over time for women, but not for men. However, when the nonlinearity is taken into account and the age premium for twenty years experience is calculated from these coefficients (Table 3.4), it is clear that the advantage enjoyed by older male and females increases between 1970 and 1995—though it increases more for women.

[7] The calculation was approximate for the 1971 Census because only a range of weeks worked and a range of hours worked were available for each individual.

Table 3.4 Education and Age Premiums for Men and Women in the Business Sector					
	1970	1980	1985	1990	1995
Men					
Any University Degree vs. Any High School Premium	43.1	35.1	33.5	38.3	38.7
Age 40 vs. Age 20 Premium	39.8	43.6	53.8	50.2	52.2
Women					
Any University Degree vs. Any High School Premium	33.0	31.9	29.5	38.5	39.2
Age 40 vs. Age 20 Premium	14.8	27.4	39.4	36.2	42.6

The elementary school disadvantage relative to high school also increases over time and once more this is greater for women than for men. Having a post-secondary degree or a university degree also becomes more important over time for women, but less so for men. Indeed the premium for university for men stays relatively constant though it increases for women.

Other socio-economic characteristics are significant. Being married increases the wage rate, but more for men than women. In the former case, the marriage premium falls over time. Being in a large city provides a higher wage, more so for women than for men. The greater the number of children, the lower is the wage. And this matters more for women than for men. Immigrants receive lower wages, especially if they are recent arrivals. Speaking a different language at home than is used at work is also associated with a lower wage rate. Part-time workers receive lower wages as well. There are also substantial industry differences, with the premium on financial and banking services increasing over time.

More important, we find that the removal of all socio-economic characteristics but the age and education variables has the effect of lowering the education and age premiums. But the effect is not large. As such, labour compositional changes estimated using the BLS and JGF methods should be similar.

The estimated coefficients were then used to derive separate predicted wage rates for men and women using the formula below:

Predicted wage rate = (new intercept) + (regression-coefficient-for-age x age) + (regression-coefficient-for-age-squared x age-squared) + (regression-coefficient-for-elementary-education-dummy x elementary-education-dummy) + (regression-coefficient-for-postsecondary-education-dummy x post-secondary-education-dummy) + (regression-coefficient-for-university-degree-dummy x university-degree-dummy).

The intercept for this equation was calculated as the sum of the estimated intercept plus the sum of the products of the remaining regression coefficients times the proportion of the regression sample with that characteristic.

Predicted wage rates were calculated for all workers in the Census, whether paid, unpaid, or self-employed, who had positive annual hours. Predicted incomes for each individual were calculated as the product of the predicted wage rate and annual hours. Predicted wage shares for each category of worker (stratified by the age, education, gender categories outlined in Table 3.3) were calculated as the quotient of the predicted income for the category divided by the total predicted income over all categories.

Table 3.5 Average Annual Growth of Labour Composition in the Canadian Business Sector (Percent): A Comparison of JGF and BLS Methods

Period	JGF Method (1)	BLS Method (2)	BLS Categories and Data, JGF Weights (3)	BLS Data and Weights, JGF Age Categories (4)	BLS Data and JGF Weights and JGF Age Categories (5)
1970-1995	0.57	0.45	0.58	0.43	0.56
Subperiods					
1970-1980	0.33	0.34	0.46	0.33	0.45
1980-1985	0.51	0.22	0.37	0.22	0.36
1985-1990	0.68	0.63	0.82	0.57	0.75
1990-1995	1.00	0.72	0.81	0.68	0.77

Changes in labour services input, total hours worked, and labour composition were then calculated in the same manner as in the Canadian JGF approach described in earlier sections, the differences being that it is the estimated rather than the actual wages that are employed and that the strata are slightly different.

3.4.2 A Comparison of changes in the labour composition index for the business sector using JGF and the BLS

The average annual growth of labour composition estimated using the BLS method is presented in Column 2 of Table 3.5 along with a comparison to estimates using the JGF method (Table 3.5, column 1).

The JGF method generally produces a slightly higher growth of labour composition in the Canadian business sector over the 1970-1995 period than the BLS method, but the results are close for the 1970-1980 and 1985-1990 periods. Moreover, they are much closer than the two U.S. results that differ by about 0.5 percentage points over the period (BLS, 1993).

There are several reasons that the JGF measures may be different from those of the BLS. As pointed out previously, the JGF method uses average wage rates across strata that differ by various key factors, i.e., education. These differences may also reflect other characteristics that are correlated with education. The BLS method corrects for these other differences and considers only the marginal effect of education. To estimate the effect of moving from the BLS to the JGF technique, we generate new JGF estimates using the BLS categories of Table 3.1 but the average wage rates appropriate to the JGF technique (Table 3.5, column 3). Each of the new estimates of the growth in labour services due to changes in labour composition is slightly higher than before.

The number of categories chosen might also be expected to make a difference in the calculations. The BLS method that is used here discriminates more finely with respect to age; the JGF method used here discriminates more finely by separating self from paid employment. The BLS approach has 480 categories in all, the JGF has 112. When we use the BLS method but JGF age-categories, the estimates decline slightly (Table 3.5, column 4).

Table 3.6 Average Annual Growth of Labour Composition in Canada and U.S.

	Annual Growth of Labour Composition (%)
JGF Method, the 1961-1995 Period	
Canada	0.63
United States*(Ho and Jorgenson, 1998)	0.51
BLS Method, the 1970-1990 Period	
Canada	0.38
United States (BLS, 1993)	0.27

* The labour composition estimate for the U.S. by Ho and Jorgenson (1998) is for the private sector that excludes the government but includes the employees of private households and nonprofit institutions. Labour composition for Canada is for the business sector.

The results of making both sets of changes—that is, using the data set that was employed for the BLS estimates, but using the JGF methodology, and the JGF age categories is presented in Table 3.5, column 5. Most of the gap between the two estimates is now accounted for.

The remaining differences are due to three factors. First, the hours and earnings used in the BLS and JGF calculations are not completely the same. After 1976, the JGF hours data are reconciled with the hours data from the LFS for each of the worker characteristics. The JGF hourly earnings data are reconciled with the hourly earnings data from the SCF and SLID. But this was not done for the BLS estimates. Second, the JGF approach treats the self-employed differently both by making them a separate category and in the way that their wage rate is calculated. The JGF technique assigns the average industry wage rate of the employed to the self-employed in the same industry. The BLS technique assigns the self-employed the same wage rate as paid employees of the same age and education class.

3.5. Comparison of Labour Compositional Changes between Canada and the U.S.

Methodological differences in the measurement of labour composition make international comparisons risky. Nevertheless, we present a comparison here to an estimate provided by Ho and Jorgenson (1998), who use the JGF method to estimate labour composition index for the U.S. private sector. Much like our study, they disaggregate hours worked by gender, age, education and class of workers. They also employ the same definition of the private business sector as is adopted here. Table 3.6 presents average annual growth rates of labour composition in the Canadian business sector and the U.S. private sector over the 1961-1995 period. Since 1961, the annual growth rate of labour composition has averaged 0.63% in Canada, compared with 0.51% in the United States.

Canada-U.S comparisons using a BLS-type method for a shorter period are provided in the bottom panel of Table 3.6. While the JFG estimates are quite similar in terms of methodology, there are more differences for the BLS methodology. The U.S. BLS method uses slightly different education levels and an estimate of experience on the job rather than age to create categories. Corresponding education categories and experience variables could not be created with the Canadian data. Nevertheless, the BLS-type results are of the same order of magnitude for both countries. As with the JGF estimates, Canada is about 0.10% higher than the United States.

Table 3.7 Average Annual Growth of Labour Productivity in the Business Sector (%)			
Period	Output Per Hour (1)	Contribution from Labour Composition (2)	Output Per Unit of Labour Services (3)
1961-2000	1.98	0.42	1.36
Sub-periods			
1961-1973	3.67	0.57	2.83
1973-1979	1.44	0.06	1.35
1979-1988	1.06	0.39	0.47
1988-1995	1.23	0.62	0.33
1995-2000	1.70	0.30	1.39

3.6 Implication of Labour Compositional Changes for Labour Productivity Growth

Since labour services growth is higher when differences across worker categories are weighted by a proxy for their relative productivity, the resulting estimates of labour productivity and multifactor productivity will be lower. Existing measures that do not consider labour compositional change in effect do not consider the causes of output growth that arise from this compositional change—from increasing the share of hours worked accounted for by higher quality workers.

Labour compositional changes are an important source of labour productivity growth. The contribution of labour compositional changes to the growth of output per hour worked for the business sector using the JGF estimates developed earlier is presented in Table 3.7. Column 1 contains the annual productivity growth rate that is derived from using straight hours worked. Column 2 contains the contribution of the usual labour productivity measure that comes from changes in labour composition. The contribution of labour composition to the growth of output per hour equals the change in labour composition times the average share of labour compensation in value-added. Column 3 contains the increase in output per unit of labour services, where growth in labour services is calculated using the JGF method.

For the 1961-2000 period, labour compositional changes contributed 0.42 percentage points to the 1.98% annual growth of output per hour. In the period prior to 1973, labour compositional changes contributed 0.57 percentage points to the growth of output per hour. It then fell substantially in the subsequent two periods. The importance of labour composition for labour productivity growth increased in the 1988-1995 period. For that period, labour composition accounted for 0.62 percentage points of labour productivity growth. After 1995, 0.30 percentage points of the growth in output per hour came from changes in labour composition.

Without the correction, labour productivity grew over the period from 1961-2000 by 1.98% per year; after the correction, it grew by only 1.36%. For the business sector, taking the effect of labour composition into account narrows the gap in labour productivity growth between the 1961-1973 period and the 1973-1979 period, but not between the 1961-1973 period and the 1979-1988 period.

3.7 Conclusion

This chapter has examined the effect of relaxing the assumption that labour is homogeneous when estimating rates of growth of labour inputs. In doing so, it calculates an index of labour services that weights the rates of growth of hours worked in different groups of workers by their relative productivity (proxied by relative wage shares).

Two separate approaches were adopted. The first proxies relative productivity by average wages in a category. The second uses multivariate analysis to estimate the marginal effects of key characteristics like education and age along with other variables like marital status.

Using both approaches, we find that the weighted rate of growth of labour services—a measure that takes into account the differences in relative productivity of different worker categories—is higher than growth rates derived from the straight sum of hours worked—the traditional measure that has been used in Canadian estimates of productivity growth. This difference is defined as the compositional growth effect (sometimes referred to as the quality effect) and comes from differential rates of growth of hours worked across different labour types.

The fact that the compositional effect is positive means that output growth in Canada has partly arisen because hours-worked have been increasing faster in those worker groups that have higher productivity. Because of this, productivity estimates that are adjusted downward for labour compositional changes are lower than those based on the sum of hours worked across all worker categories.

The study finds that rising educational attainment explains almost all of the growth in labour compositional changes in Canada. The changes in the gender and age mix of the Canadian workforce have offsetting effects on labour composition growth.

We take from this several lessons for the productivity program.

The technique adopted here to correct for heterogeneity in labour services is based on the notion that relative wage rates approximate relative marginal productivity. It is this assumption that underlies much of the productivity literature. For example, estimates of multifactor productivity weight labour by labour's share of GDP and capital by capital's share. And in doing so, practitioners generally assume that they are doing so to capture the marginal productivity of each factor. Therefore, making such assumptions in using wage share weights in aggregating different types of labour is in keeping with the spirit of present practices. However, there is still the question as to how far this assumption should be pushed. Relative wages probably do not reflect relative productivity in all labour markets. Assuming that relative male/female wages fully reflect marginal productivity differences and not discrimination is a case in point.

The issue then is one of deciding which characteristics to take into account when making corrections for labour heterogeneity. Fortunately for this analysis, there is evidence to suggest that education is the most important factor empirically. Focusing on this and age as a proxy for experience is sufficient for practical purposes. Therefore, gender will not be used in the estimates that will be published.

There is still the issue of the methodology that should be pursued. There are substantial differences in the U.S. estimates produced by the JFG and the BLS approaches. Both yield quite similar estimates in Canada when the categories that are used for the analysis are harmonized and calculated using very similar databases. The estimate of labour

compositional change in Canada is not very sensitive to which of the two types of estimation approaches are adopted.

One of the major advantages of the BLS method is that it uses an imputed experience variable rather than age to capture the advantages that older workers gain from experience. But since a good estimate of actual work experience is not available for Canada, the BLS method loses some of the potential advantage over the JGF method. Moreover, an experimentation of wage regressions from various household surveys (SCF) shows year-over-year variations in the estimated coefficients on education and age variables, especially at industry levels which introduces measurement errors in the BLS-type method. Finally, we also find that the JGF method is computationally much simpler for Canada than the BLS method. Since the JGF and BLS results are quite similar, the JGF method will be adopted for calculating changes in Canadian labour composition.

Finally, a caveat is in order for those who will use the new estimates of labour productivity that take into account changes in the quality of labour. The fact that education is so important raises a separate issue as to how the new productivity estimates should be interpreted. To simply say that productivity growth is lower than some might otherwise have thought is misleading. It is lower in the business sector. But this improvement has come from improved output levels of the education sector, which are not included in the business sector productivity estimates. These improvements should be attributed to the public sector. Total productivity gains are not reduced. They are simply reallocated.

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Appendix Table 3.A1 Annual Average Growth of Labour Productivity and Labour Composition by Industry, 1961-1997, Using the JGF Method (%)

	Industry	Value-added Per Hour	Value-added Per Unit of Labour	Labour Composition
1	Agricultural and Related Service	3.74	3.09	0.65
2	Fishing and Trapping	-0.04	-0.58	0.54
3	Logging and Forestry	2.25	1.77	0.48
4	Gold Mines	1.32	0.53	0.79
5	Other Metal Mines	1.13	0.66	0.48
6	Iron Mines	3.49	3.01	0.47
7	Asbestos Mines	-0.33	-0.79	0.46
8	Other Non-metal Mines (except coal)	5.59	4.94	0.65
9	Salt Mines	4.95	4.46	0.49
10	Coal Mines	6.28	5.68	0.60
11	Crude Petroleum and Natural Gas	-1.42	-1.93	0.51
12	Quarry and Sand Pit Industries	3.34	2.87	0.46
13	Service Industries Incidental to Mineral Extraction	0.20	-0.33	0.53
14	Meat and Meat Products (except poultry)	0.18	-0.07	0.24
15	Poultry Products	0.34	-0.30	0.64
16	Fish Products	0.06	-0.36	0.42
17	Fruit and Vegetables	3.89	3.36	0.53
18	Dairy Products	1.98	1.45	0.53
19	Miscellaneous Food Products	2.07	1.41	0.66
20	Feed	4.73	4.09	0.64
21	Vegetable Oil Mills (except corn oil)	5.90	4.30	1.61
22	Biscuit	0.90	-0.07	0.97
23	Bread and Pther Bakery Products	1.09	0.46	0.63
24	Cane and Beet Sugar	1.65	1.25	0.40
25	Soft Drink	2.15	1.26	0.90
26	Distillery Products	3.39	2.33	1.06
27	Brewery Products	1.61	0.98	0.63
28	Wine	4.21	3.62	0.59
29	Tobacco Products	3.52	2.59	0.93
30	Rubber Products	3.92	3.44	0.47
31	Plastic Products	4.12	3.55	0.57
32	Leather Tanneries	1.83	1.56	0.27
33	Footwear	1.81	1.39	0.42
34	Miscellaneous Leather and Allied Products	2.49	2.03	0.47
35	Man-made Fibre Yarn and Woven Cloth	6.17	4.95	1.22
36	Wool Yarn and Woven Cloth	2.26	1.46	0.80
37	Broad Knitted Fabric	9.68	8.49	1.19
38	Miscellaneous Textile Products	2.79	2.21	0.58
39	Carpet, Mat and Rug	6.84	6.02	0.82
40	Clothing Industries Excluding Hosiery	2.59	2.32	0.27
41	Hosiery	6.01	5.71	0.30
42	Sawmill, Planing Mill and Shingle Mill Product	3.09	2.38	0.70
43	Veneer and Plywood	2.39	1.86	0.53
44	Sash, Door and Other Millwork	0.98	0.55	0.43
45	Wooden Box and Coffin	0.46	-0.15	0.61
46	Other Wood	2.02	1.36	0.66
47	Household Furniture	0.82	0.55	0.28
48	Office Furniture	2.35	0.85	1.50
49	Other Furniture and Fixtures	2.15	1.45	0.70
50	Pulp and Paper	2.17	1.64	0.53
51	Asphalt Roofing	4.39	3.40	0.99
52	Paper Box and Bag	2.16	1.42	0.73
53	Other Converted Paper Products	2.65	1.98	0.67
54	Printing and Publishing	0.37	0.07	0.30
55	Platemaking, Typesetting and Bindery	0.93	0.80	0.12
56	Primary Steel	2.13	1.60	0.54
57	Steel Pipe and Tube	5.63	5.17	0.46
58	Iron Foundries	2.77	2.23	0.54
59	Non-ferrous Metal Smelting and Refining	2.89	2.35	0.54

Appendix Table 3.A1 Annual Average Growth of Labour Productivity and Labour Composition by Industry, 1961-1997, Using the JGF Method (%) – *continued*

	Industry	Value-added Per Hour	Value-added Per Unit of Labour	Labour Composition
60	Aluminum rolling, Casting and Extruding	3.53	2.95	0.58
61	Copper and Alloy Rolling, Casting and Extruding	1.64	1.12	0.52
62	Other Rolling, Casting and Extruding Non-ferrous Metal Products	-0.34	-0.79	0.46
63	Power Boiler and Structural Metal	1.05	0.55	0.50
64	Ornamental and Architectural Metal Products	2.84	2.41	0.43
65	Stamped, Pressed and Coated Metal Products	1.32	0.80	0.52
66	Wire and Wire Products	1.76	1.22	0.54
67	Hardware, Tool and Cutlery	1.00	0.45	0.55
68	Heating Equipment	2.30	1.58	0.72
69	Machine Shop	1.90	1.27	0.63
70	Other Metal Fabricating	1.96	1.48	0.48
71	Agricultural Implement	3.07	2.77	0.31
72	Commercial Refrigeration and Air Conditioning Equipment	4.51	3.72	0.79
73	Other Machinery and Equipment	1.48	1.00	0.49
74	Aircraft and Aircraft Parts	1.53	1.02	0.51
75	Motor Vehicle	6.06	5.69	0.37
76	Truck and Bus Body and Trailer	3.48	3.11	0.37
77	Motor Vehicle Parts and Accessories	4.56	4.12	0.44
78	Railroad Rolling Stock	1.05	0.52	0.53
79	Shipbuilding and Repair	1.63	1.06	0.57
80	Miscellaneous Transportation Equipment	5.12	4.09	1.03
81	Small Electrical Appliance	4.54	4.16	0.38
82	Major Appliance (electric and non-electric)	4.85	4.35	0.50
83	Other Electrical and Electronic Products	2.75	2.04	0.72
84	Record Player, Radio and t.v. Receiver	4.70	4.24	0.46
85	Communication and Other Electronic Equipment	4.61	4.00	0.61
86	Office, Store and Business Machines	13.96	13.30	0.67
87	Communication and Energy Wire and Cable	2.32	1.78	0.54
88	Battery	2.43	1.94	0.49
89	Clay Products	1.62	1.94	-0.32
90	Hydraulic Cement	1.56	0.96	0.60
91	Concrete Products	1.38	0.77	0.61
92	Ready-mix Concrete	1.66	1.27	0.38
93	Glass and Glass Products	3.59	3.24	0.35
94	Miscellaneous Non-metallic Mineral Product	2.77	2.12	0.65
95	Refined Petroleum and Coal Products	4.47	3.84	0.63
96	Industrial Chemicals n.e.c.	5.29	4.66	0.64
97	Chemical Products n.e.c.	3.54	2.90	0.64
98	Plastic and Synthetic Resin	5.62	4.89	0.73
99	Pharmaceutical and Medicine	4.71	4.16	0.55
100	Paint and Varnish	0.88	0.42	0.46
101	Soap and Cleaning Compounds	3.56	3.06	0.49
102	Toilet Preparations	1.96	0.80	1.17
103	Other Manufacturing	2.60	2.07	0.53
104	Jewellery and Precious Metals	-0.45	-0.59	0.14
105	Sporting Goods and Toys	3.22	2.77	0.45
106	Sign and Display	0.31	0.32	-0.01
108-116	Construction	0.94	0.43	0.51
117	Air Transport and Related Service	0.78	0.20	0.58
118	Railway Transport and Related Service	7.11	6.61	0.49
119	Water Transport and Related Services	3.06	2.60	0.46
120	Truck Transport	2.41	1.98	0.44
121	Urban Transit Systems	-2.16	-2.40	0.24
122	Interurban and Rural Transit Systems	0.13	-0.32	0.45
123	Miscellaneous Transport Services	0.15	-0.28	0.43
124	Pipeline Transport	2.38	1.77	0.62
125	Storage and Warehousing	1.77	1.38	0.39
126	Telecommunication Broadcasting	2.22	1.72	0.50
127	Telecommunication Carriers	5.88	5.22	0.66

Appendix Table 3.A1 Annual Average Growth of Labour Productivity and Labour Composition by Industry, 1961-1997, Using the JGF Method (%) – *concluded*

Industry		Value-added Per Hour	Value-added Per Unit of Labour	Labour Composition
128	Postal and Courier Service	0.65	0.42	0.22
129	Electric Power Systems	2.48	1.77	0.70
130	Gas Distribution Systems	2.87	2.37	0.50
131	Water Systems and Other Utility n.e.c.	2.59	2.09	0.50
132	Wholesale Trade	2.39	1.94	0.44
133	Retail Trade	1.97	1.65	0.32
134	Finance and Real Estate	-0.35	-0.85	0.49
135	Insurance	2.03	1.68	0.35
137	Other Business Services	2.44	1.43	1.01
138	Professional Business Services	-0.27	-0.60	0.34
139	Advertising Services	-1.46	-1.28	-0.19
140	Educational Service	-0.36	-0.92	0.56
141	Other Health and Social Service	-1.03	0.29	-1.32
142	Accommodation and Food Services	-0.21	-0.68	0.47
143	Motion Picture and Video	-0.62	-0.60	-0.02
144	Other Amusement and Recreational Services	-0.07	-0.76	0.69
145	Other Personal Service	0.05	-0.39	0.44
146	Laundries and Cleaners	0.37	0.13	0.24
147	Membership Organizations (excluding religions) and Other Services	1.24	1.02	0.22

Appendix Table 3.A2 Women's Log Wage Rate Regressions Using Canadian Census Data (Private Industry Employees or Incorporated Self-employed)

Independent Variable	Coefficient Values for Census Years:				
	1971	1981	1986	1991	1996
Intercept	0.267	0.699	0.681	0.969	0.956
Age	0.023	0.040	0.054	0.050	0.050
Age-squared	-0.00026	-0.00044	-0.00057	-0.00053	-0.00048
Elementary school	-0.146	-0.169	-0.217	-0.223	-0.214
Post-secondary	0.088	0.088	0.066	0.122	0.127
Degree	0.330	0.319	0.295	0.385	0.392
Now-married	0.078	0.069	0.092	0.055	0.085
Immigrated Within 6 Years	-0.137	-0.243	-0.289	-0.270	-0.346
Immigrated Earlier	-0.025	-0.044	-0.052	-0.044	-0.084
Different Home Language	-0.006	-0.037	-0.045	-0.089	-0.111
Currently Part-time	-0.533	-0.071	-0.126	-0.092	-0.110
In Large City (>100,000)	0.136	0.109	0.125	0.156	0.134
Full-time this Year and Last	-0.183	-0.029	-0.005	-0.090	-0.064
Has One Child	-0.023	-0.028	-0.027	-0.023	-0.004
Has 2 or 3 Children	-0.052	-0.033	-0.020	-0.020	0.022
Has 4 or More Children	-0.103	-0.103	-0.082	-0.099	-0.008
Prince Edward Island	-0.064	-0.031	-0.053	-0.031	*0.009
Nova Scotia	*-0.005	-0.025	-0.034	-0.017	0.024
New Brunswick	0.065	0.033	0.028	0.040	0.067
Quebec	0.206	0.146	0.091	0.135	0.199
Ontario	0.236	0.115	0.096	0.233	0.311
Manitoba	0.087	0.041	0.017	0.019	0.077
Saskatchewan	0.022	0.117	0.068	-0.058	0.060
Alberta	0.171	0.221	0.163	0.137	0.202
British Columbia	0.267	0.284	0.177	0.212	0.349
Yukon, Northwest Territories and Nunavit	0.422	0.356	0.316	0.362	0.439
Manufacturing	0.110	0.113	0.161	0.208	0.128
Communication/Transport/Energy	0.200	0.246	0.332	0.332	0.261
Financial and Banking Services	0.078	0.163	0.220	0.262	0.212
Commercial Services	-0.047	-0.014	0.022	0.064	-0.007
Number of Observations	606,190	417,194	534,570	542,030	586,776
R-squared	0.297	0.198	0.300	0.247	0.286

* Statistically not significant

Note: omitted category of multiple categories: some high school, primary industries, Newfoundland.

Appendix Table 3.A3 Men's Log wage Rate Regressions Using Canadian Census Data (Private Industry Employees or Incorporated Self-employed)

Independent Variable	Coefficient Values for Census Years:				
	1971	1981	1986	1991	1996
Intercept	0.168	0.745	0.689	1.126	1.165
Age	0.053	0.057	0.069	0.061	0.059
Age-squared	-0.00055	-0.00059	-0.00070	-0.00060	-0.00055
Elementary School	-0.143	-0.159	-0.172	-0.180	-0.172
Post-secondary	0.111	0.082	0.069	0.106	0.109
Degree	0.431	0.351	0.335	0.383	0.387
Now-married	0.180	0.154	0.154	0.135	0.118
Immigrated Within 6 Years	-0.154	-0.245	-0.312	-0.347	-0.395
Immigrated Earlier	-0.036	-0.064	-0.062	-0.068	-0.101
Different Home Language	-0.027	-0.056	-0.070	-0.107	-0.133
Currently Part-time	-0.314	-0.218	-0.245	-0.224	-0.242
In Large City (>100,000)	0.085	0.076	0.089	0.097	0.071
Full-time this Year & Last	-0.164	-0.079	-0.024	-0.106	-0.046
Has One Child	0.008	0.010	-0.013	-0.001*	0.001
Has 2 or 3 Children	0.076	0.050	0.025	0.038	0.035
Has 4 or More Children	0.070	-0.040	-0.038	-0.059	-0.077
Prince Edward Island	-0.262	-0.177	-0.155	-0.158	-0.163
Nova Scotia	-0.073	-0.067	-0.026	-0.040	-0.091
New Brunswick	-0.035	0.014	0.039	0.038	-0.002
Province of Quebec	0.099	0.084	0.085	0.088	0.067
Ontario	0.153	0.099	0.113	0.176	0.150
Manitoba	0.022	0.004	-0.009	-0.057	-0.061
Saskatchewan	-0.030	0.062	0.021	-0.083	-0.052
Alberta	0.108	0.209	0.162	0.080	0.080
British Columbia	0.200	0.248	0.188	0.168	0.191
Yukon, Northwest Territories and Nunavit	0.296	0.218	0.233	0.246	0.229
Manufacturing	0.035	0.085	0.116	0.113	0.096
Communication/Transport/Energy	0.023	0.092	0.141	0.118	0.075
Financial and Banking Services	0.029	0.114	0.128	0.126	0.206
Commercial Services	-0.087	-0.082	-0.069	-0.048	-0.084
Number of Observations	1,337,216	804,416	895,317	871,912	929,023
R-squared	0.390	0.375	0.462	0.368	0.391

* Statistically not significant

Note: omitted category of multiple categories: some high school, primary industries, Newfoundland

4 A Comprehensive Revision of the Capital Input Methodology for Statistics Canada's Multifactor Productivity Program

Tarek M. Harchaoui and Faouzi Tarkhani

4.1. Introduction

Measuring economic performance involves comparisons in terms of output, inputs (capital, labour and intermediate inputs) or productivity measures across industries and over different time periods. The productivity accounts have provided a useful framework for organizing the information required for comparisons of this type. Productivity accounts decompose rates of change in output into the portions that arise from increases in various inputs and a residual that is defined as multifactor productivity. This factor encompasses technical change, organizational change and all other factors that are not subsumed in the input growth measures.

Comparisons of productivity performance across industries or countries are of great interest from an academic point of view. They are also of interest from the public policy perspective. Evaluation of alternative policies involves comparison of the present state of affairs and possible alternative states associated with changes in policy.

Until 1987, productivity figures produced by Statistics Canada were expressed in terms of output per employee—a simple measure of labour productivity. In the early 1990s, Statistics Canada introduced a better measure of labour input that makes use of the number of hours worked. The measure of labour productivity growth reflects not only changes in technology but also changes in the availability of capital per hour—a result of capital accumulation rather than of improved labour efficiency.

For this reason, Statistics Canada followed the advice of professional economists and developed the multifactor productivity program to better measure the efficiency with which several inputs are jointly used. Multifactor productivity growth measures the increase in output that is achieved beyond the increase in all inputs—both capital and labour. It can arise from outward shifts in the aggregate production function brought about by technological change, and, under certain conditions, the latter can be measured by changes in the multifactor productivity measure alone. When these conditions do not hold, alternative methods are used to separate out the technological shift component from other factors like the exploitation of scale economies that are at work.[1]

Multifactor productivity measurement involves comparing changes in output with changes in inputs. The microeconomic theory of the firm uses a 'production function' to formally describe the relationship between the services of inputs and output. Capital is, of course, one type of input. However, capital goods do not neatly conform with the

[1] See Baldwin, Gaudreault and Harchaoui (2001) for an illustration of the parametric approach to productivity measurement.

simple production model. Among other things, they are not consumed in production. Nonetheless, capital goods must specifically be deployed in production for a period of time in order to *render services*. A measure of capital input which would be consistent with production theory is therefore the quantity of the *flow of services* provided by capital goods.

Because many different types of capital goods are used in production, an aggregate measure of the capital stock or of capital services must be constructed. For net stocks used in the *wealth* accounts this is a straightforward matter of summing estimates for different types of assets. In so doing, market prices serve as aggregation weights. The situation is different for the capital services estimates needed for *productivity* analysis. Typically, each type of asset is associated with a specific flow of capital services and strict proportionality is assumed between capital services and capital stocks at the level of individual assets. This ratio may not be the same, however, for different kinds of assets, so that the aggregate stock derived from the wealth accounts and the flows covering different kinds of assets needed for productivity analysis may diverge. A single measure of capital stock cannot serve both purposes except when there is only one single homogenous capital good.

To better understand why this is the case, consider the process by which multifactor productivity is estimated. Multifactor productivity is defined as the difference between growth in output Q and the contributions that capital K and labour L make to the growth in output as a result of the use of additional units of capital and labour— $C(\Delta K)$ and $C(\Delta L)$, respectively.

$$MFP = \Delta Q - C(\Delta K) - C(\Delta L)$$

The contribution that labour or capital make to output growth is just the marginal product of labour (capital) multiplied by the change in labour (capital) devoted to production. If the production function is characterized by constant returns to scale and prices of inputs (labour and capital) equal to their marginal revenue product, then the share of labour in total output (s_L) or the share of capital in total product (s_K) may be taken as representing the marginal product of each factor.

Thus

$$MFP = \Delta Q - s_K(\Delta K) - s_L(\Delta L).$$

In a world where all assets have the same marginal product, changes in capital may be estimated by simply summing the value of all assets and calculating changes therein over time. But if there are n assets, each with a different marginal product of capital s_{K_i}, then the appropriate formulae for estimating the effect of capital is

$$C(\Delta K) = s_{K_1}\Delta K_1 + s_{K_2}\Delta K_2 + .. + s_{K_n}\Delta K_n,$$

where s_{K_a} can be approximated by the share of total output that goes to each type of capital a $(a = 1,2,...n)$.

The appropriate weights then to estimate changes in capital stock are the relative shares of each asset in total capital compensation. In order to estimate these shares, we need to calculate the unit price of each type of asset (c_a)—since the share of each asset in total capital costs is just

$$s_{K_1} = \frac{c_1 K_1}{\sum_a c_a K_a} .$$

A simple measure of capital stock may not be the appropriate measure of capital for an aggregate production function analysis when there is a wide array of heterogeneous assets that have different productive characteristics. Only if asset prices are the same will it be possible to simply sum the dollar values of all assets and aggregate them. In this chapter, we discuss the methodology that has been employed to estimate the various asset prices c_a of different assets a.[2]

To address this measurement problem, Griliches and Jorgenson (1966) and Jorgenson and Griliches (1967) introduced "constant quality" indices of capital services, also called capital input, which recognize that tangible assets, purchased for the same number of dollars, have different service lives, depreciation rates, tax treatments, and ultimately different marginal products.

Constant quality indexes of capital services use an asset-specific "user cost of capital," as derived by Jorgenson (1963) and further developed in Hall and Jorgenson (1967), to aggregate heterogeneous capital assets. This user cost approach has important advantages over the simpler capital stock approach, which uses acquisition prices to weight different assets. Weighting assets by their user cost, which equals the marginal product in a competitive equilibrium, effectively incorporates differences in the productive contribution of heterogeneous investments as the composition of investment and capital changes. In this case, changes in aggregate capital input have two distinct components—changes in the quantity of capital of a given type, and changes in the composition of the various types of assets with different marginal products and user costs. This second effect—arising from the change in the importance of different capital types in the aggregate capital stock—is sometimes referred to as the change in the "quality" of capital services or the compositional effect of changing the nature of the bundle of assets. It explicitly captures substitution between heterogeneous assets in response to changing relative prices of different assets.

While Jorgenson's pioneering efforts have provided the broad outlines of the framework needed to overcome the lack of directly observable and measurable prices of capital services, providing a link between the model's theoretical structure and its application has been more difficult. In particular, there is a considerable difference between the rental price as a theoretical paradigm and its real world empirical application. This chapter discusses some of the issues that have to be resolved in order to bridge this gap.

[2] The same issue is relevant when it comes to estimating the change in hours-worked and is discussed in chapter 3 of this volume.

Accordingly, the primary purpose of this paper is to present a systematic discussion of the conceptual and measurement issues related to measuring the set of rental price components. The issues developed here are of fundamental importance in the measurement of capital input used by the multifactor productivity framework. The manner in which the user cost of capital components are measured makes them particularly vulnerable to error-in-variable problems. Unfortunately, there has been both little discussion of the concepts behind the components of the rental price and little testing of the impact of alternative measures of these components on the quality of capital input estimates (see Diewert and Lawrence 1999; Bernstein 2000).

We first review the guidance provided by economic theory in discriminating among alternative rental price formulae employed in the empirical literature. This results in a set of five possible rental price measures that we then evaluate in the context of the multifactor productivity growth accounting framework. The empirical evaluation procedure is based on a comparison of the five alternative rental price estimates using a common data set covering 122 industries (1980 SIC) of the Canadian business sector over the 1961-2000 time period, with 28 distinct types of capital assets.

The chapter is organized as follows. Section 4.2 provides a comprehensive summary of the concept of capital services and its underlying assumptions. Section 4.3 discusses the domain of definition of capital stock and the aggregation techniques required for the construction of capital input estimates. Section 4.4 develops, at length, the concepts and practical considerations that underlie the cost of capital measure. Section 4.5 analyzes the estimates of the user cost of capital and the capital assets. This section also evaluates the effect of alternate measures of the user cost on the growth of capital composition. Concluding remarks are drawn in Section 4.6 on the role of capital in the Canadian business sector's economic growth and a comparison of Canada-U.S. productivity performance. Appendix 4.A describes the sources of the tax variables used in the construction of the user cost of capital estimates. Appendix 4.B provides a formal description of the procedures used to arrive at the concept of aggregate capital services.

4.1.1 Capital in the Productivity Literature

This section provides a detailed summary of the methodology used to calculate capital services. Starting with investment data, we calculate capital stocks using the perpetual inventory method, and then estimate the user cost of capital for each asset from tax records and national accounts data.

These stocks are then aggregated using the user cost of capital to weight individual assets to form an estimate of the flow of capital services. A reader not interested in the nuances of capital theory and measurement can skip this section for our empirical results in Sections 4.4 and 4.5.

Our objective is to construct a measure of aggregate capital services that can account for the heterogeneity in investment goods and the changing composition of the Canadian capital stock, yet also remain tractable. This tractability issue raises important conceptual issues about the fundamental nature of capital. One could argue that each piece of capital is distinct and must be included separately in a production function, i.e., automobiles are not perfect substitutes for tractors or a personal computer with a 486

chip is not a substitute for one with a Pentium-Pro chip. While desirable, such an approach is obviously impossible to implement given the large number of assets involved.[3]

Therefore, our model of production assumes output is a function of aggregate capital services, $\tilde{K}_t$ where $\tilde{K}_t = f(K_{1t}, K_{2t}, ..., K_{At})$ is an aggregate of services from A heterogeneous assets. Moreover, these services are separable from other inputs like labour $L_t = f(L_{1t}, L_{2t}, ..., L_{Tt})$, and K_{at} itself is an average of individual items, e.g., the 'aircraft' asset includes many different types, models, and vintages. The user cost of asset a, c_{at}, represents the average rental cost per effective unit of "aircraft." Using these rental prices, which equal the marginal product of capital in competitive equilibrium, the many heterogeneous $\tilde{K}_{at}$'s can be aggregated into a single index of capital services, $\tilde{K}_t$.

4.2 The Concepts: Stocks and Flows

Investment involves the acquisition of capital goods at a given point in time. The quantity of investment is measured in the same way as the durable goods themselves.[4] For example, investment in equipment is the number of machines of a given specification and investment in buildings is the number of buildings of a particular description. The price of acquisition of a durable good is the unit cost of acquiring a piece of equipment or a structure.

In contrast to investment, capital services are measured in terms of the use of a durable good *for a stipulated period of time*. For example, a building can be leased for a period of years, an automobile can be rented for a number of days or weeks, and computer time can purchased in seconds or minutes. The price of the services of a durable good is the unit cost of using the good for a specified period.

In the durable goods model of production, capital input plays a role that is analogous to that of any other input. But the distinguishing feature of capital is that durable goods provide services at different points of time. The capital services provided by a given durable good at a point in time are proportional to the initial investment. Durable goods acquired at different points of time are usually referred to as different vintages of capital.

The flow of capital services then needs to be constructed as a quantity index of capital inputs from durable goods of different vintages. The flow of capital services from a set of durable goods of different vintages is a weighted sum of past investments. The weights correspond to the relative efficiencies of the different vintages of capital.

The relative efficiency of a capital good is assumed to depend on the age of the good and not on the time it is acquired. Replacement requirements are determined by losses in efficiency of existing capital goods as well as by actual physical retirement of capital goods. When a capital good is retired, its relative efficiency drops to zero. The relative

[3] A parallel problem arises in the modelling of labour input where each worker is different, but some averaging is necessary to construct tractable measures of labour. See Ho and Jorgenson (1999) for example.

[4] This section relies on Jorgenson (1995, pp. 28-45)

efficiencies of capital goods of different ages can be described by a sequence of non-negative numbers $d_o, d_1, \ldots$, the relative efficiency of a new capital good is normalized at unity, and the relative efficiency is assumed non-increasing, so that: $d_0 = 1$ and $d_\tau - d_{\tau-1} \geq 0 \quad (\tau = 0,1,\ldots)$. It is also assumed that every capital good is eventually retired or scrapped so that relative efficiency eventually drops to zero, that is $\lim_{\tau\to\infty} d_\tau = 0$.

As an illustration of patterns in the decline in relative efficiency, we can consider the declining balance pattern, where efficiency is assumed to decline geometrically $d_\tau = (1-\delta)^\tau \quad (\tau = 0,1,\ldots)$.[5]

To characterize capital as a factor of production, consider the following production function that is homothetically separable in the services of different vintages of capital

$$Y_t = F\left(f\left(K_{t,0}, K_{t,1}, \ldots, K_{t,\tau}, \ldots\right), L_t, M_t, t\right),$$

where the function F is homogeneous of degree one in the services from capital goods of different ages. If we assume that the quantity index of capital input K_t is characterized by perfect substitutability among the services of different vintages of capital, we can write this index as the sum of these capital services

$$K_t = \sum_{\tau=0}^{\infty} K_{t,\tau}\,.$$

Under the additional assumption that the services provided by a durable capital good are proportional to initial investment in this good, we can express the quantity index of capital input in the form

$$K_t = \sum_{\tau=0}^{\infty} d_\tau I_{t-\tau}\,. \tag{1}$$

The flow of capital services is a weighted sum of past investments with weights given by the relative efficiencies $\{d_\tau\}$ of capital goods of different ages.

[5] There are two other patterns of decline in efficiency in the durable goods model of production that are often studied. In the one-hoss shay pattern, efficiency is constant over the life-time of the capital good. Where T is the lifetime, relative efficiency is is given by

$$d_\tau = \begin{cases} 1 & (\tau = 0,1,\ldots,T-1) \\ 0 & \text{otherwise.} \end{cases}$$

In the straight-line pattern, efficiency declines linearly over the lifetime of the capital good

$$d_\tau = \begin{cases} 1 - \dfrac{\tau}{T} & (\tau = 0,1,\ldots,T-1) \\ 0 & \text{otherwise.} \end{cases}$$

Capital goods decline in efficiency at each point of time, giving rise to needs for a replacement if productive capacity is to be maintained. Taking the first difference of the expression for capital stock in terms of past investments and assuming a geometric declining pattern for d_τ, we obtain

$$\begin{aligned} K_t - K_{t-1} &= I_t - \delta \sum_{\tau=1}^{\infty} (1-\delta)^{\tau-1} I_{t-\tau} \\ &= I_t - \delta K_{t-1}, \end{aligned} \tag{2}$$

which is the perpetual inventory formulation of capital stock.

4.2.2 A Dual Interpretation of the Capital Concept

In the durable goods model of production, the price counterpart of capital stock, K_t, is the acquisition price of investment goods, q_t. The rental prices of capital goods of different ages are proportional to the rental price of a new capital good. The constants of proportionality are the relative efficiencies $(1-\delta)^\tau$. The acquisition price of investment goods q_t is the sum of future rental prices of capital services c_t, weighted by the relative efficiencies of capital goods in each future period, $(1-\delta)^\tau$, and discounted to the present.

$$q_t = \sum_{\tau=0}^{\infty} (1-\delta)^\tau \prod_{s=1}^{\tau+1} \frac{1}{(1+r_{s+t})} c_{t+\tau+1},$$

where r_{s+t} is the rate of return in period $s+t$. In a competitive market for capital goods, ignoring taxes and uncertainty, the price of the asset will equal the discounted sum of the future rental prices from the depreciating asset.

The acquisition price of a durable good declines with the age of the good because of depreciation. Depreciation reflects both the current decline in efficiency and the present value of future declines in efficiency.

Assuming that the price reflects the expected future value of services and taking the first difference of the expression for the acquisition price of investment goods in terms of future rental, we obtain

$$q_t - q_{t-1} = -\frac{1}{(1+r_t)} c_t + \frac{(r_t+\delta)}{(1+r_t)} \sum_{\tau=0}^{\infty} (1-\delta)^\tau \prod_{s=1}^{\tau+1} \frac{1}{(1+r_{s+t})} c_{t+\tau+1},$$

and the rental price of capital services is given by

$$c_t = q_{t-1}(r_t+\delta) - (q_t - q_{t-1}). \tag{3}$$

The cost of capital is an annualization factor that transforms the acquisition price of investment goods into the price of capital input.

The durable goods model of production is characterized by price-quantity duality. In this duality, the capital stock K_t corresponds to the sum of the acquisition price of all investment goods, q_t. Capital stock is a weighted sum of past investments, while the acquisition price of investment goods is a weighted sum of future rentals. Capital input in any one period is the service flow from the capital stock available at the beginning of the period. The price of capital input is the rental price of capital services for that period.

In the definition of capital stock, the weights on past investments correspond to relative efficiencies of capital goods of different ages. These weights are also applied to future rental prices in defining the acquisition price of investment goods. Replacement requirements are generated by the decline in efficiency of a capital good with age. Depreciation results from the decline in the price of acquisition of a capital good with age. A special feature of geometrically declining relative efficiencies is that the rate of replacement and the rate of depreciation are equal to the rate of decline in efficiency δ.

4.2.3 An Heuristic Interpretation of the User Cost of Capital

When a firm purchases a durable capital input, it is not appropriate to allocate the entire purchase price q_t as a cost to the initial period when the asset was purchased. It is necessary to distribute this initial purchase (the price of the asset) across the useful life of the asset. The concept of user cost of capital c_t does just that. It represents the amount of rent that would have been charged in order to cover costs of q dollars' worth an asset.

In equation (3), the user cost of capital of an asset c_t is the per-period cost of using the services of the asset. The first term of the user cost expression $q_{t-1}(r_t + \delta)$ measures the cost of financing the asset ($q_{t-1}r_t$). This is the interest payment if a loan was taken out to acquire the asset or the opportunity cost of employing capital elsewhere than in production if the acquisition of the asset was financed from external sources. Added to the interest cost is $q_{t-1}\delta$, the cost of depreciation or the loss in value of the machine because it ages. The loss in value reflects physical decay or efficiency loss of the asset, but also the fact that its expected service life has declined by one period.

Thus, two assets may have the same value, e.g., $P_{a,t}K_{a,t} = P_{k,t}K_{k,t}$, but they may have very different rental prices. For example, if the depreciation rate of a is faster than k, then rental payments will be larger for a than for k, $c_{a,t}K_{a,t} > c_{k,t}K_{k,t}$ (ignoring differences in the tax treatment). Intuitively, if the acquisition prices are the same, a short-lived asset must provide a larger rental value per dollar to balance out the faster depreciation.

It should be noted that the formula (3) abstracts from all effects of taxation. In his later contributions, Jorgenson augments the user cost expression to incorporate the effects of corporate income taxes, tax depreciation allowances, investment tax credits and indirect taxes. It is apparent that the inclusion of tax variables comes at a non-negligible cost. For a full implementation, historical and current tax laws have to be monitored, by

type of asset and by industry, along with assumptions of assets' tax lives and estimates of business income tax rates (see Appendix 4.A at the end of this chapter).

To take into account taxes, Christensen and Jorgenson (1969) developed the following user cost formula c_{iat} for the a-th capital asset type, the i-th industry and period t

$$c_{iat} = q_{iat-1}\left\{\left(\frac{1-u_{it}z_{iat}-k_{iat}}{1-u_{it}}\right)\left[r_t+\delta_{ia}-\frac{(q^*_{iat}-q_{iat-1})}{q_{iat-1}}\right]+\phi_{it}\right\} \tag{4}$$

where ϕ_{it} is the effective rate of property taxes (nominal valued taxes assessed on the real stocks of land and structures, and $(\frac{1-uz-k}{1-u})$ is the effective rate of taxation on capital income, where u_{it} is the corporate income tax rate, z_{iat} is the present value of depreciation deductions for tax purposes on a dollar's investment in capital type a over the lifetime of the investment, and k_{iat} is the rate of the investment tax credit; $\frac{(q^*_{iat}-q_{iat-1})}{q_{iat-1}}$ is the expected capital gain (the remaining variables have already been defined above).

4.3 Construction of Capital Input

We usually cannot obtain direct measures of the prices or quantities of capital service flows. However, one important type of data, which relates directly to the 'shadow' market, is readily available: *property income*, defined as nominal revenues minus expenses for variable inputs (labour and purchased materials and services). Measures of property income for firms are readily available from accounting records. Data on property income by industry commonly are compiled as part of Input-Output Tables. In practice, property income includes depreciation allowances, interest and taxes.[6]

The measurement of the growth rate of capital services requires us to separate the growth rate of property income into components of quantity and price change. To do so, we construct detailed historical data on stock of assets K_{iat} by industry i, asset a and time period t to provide quantities using investment series and estimates of δ, depreciation (See Chapter 2 in this volume). On the price side, we estimate 'implicit rental prices' for detailed types of capital c_{iat}, so that the value of capital services $\sum_a c_{iat}K_{iat} \equiv \tilde{K}_{it}$ is equal to property income R_{it}. By substituting in equation (4) above for c_{iat}, and substituting known values for all variables except r_t, that is, depreciation, δ, tax rates, $(\frac{1-uz-k}{1-u})$, and capital gains, $\frac{(q^*_{iat}-q_{iat-1})}{q_{iat-1}}$ etc., the remaining variable r_t can be derived. Then, substituting r_t, the depreciation δ and the capital gains, $(q_t - q_{t-1})$, into the formula for c_{iat}, i.e., $c_t = q_{t-1}(r_t+\delta)-(q_t-q_{t-1})$ allows c, the rental price of capital, to be calculated.

[6] See Harchaoui, et al. (2001, pp. 155-158) for a description on the various transformations that the productivity program implements on the data from Input-Output Tables.

We construct stocks and rental prices using as much asset detail as possible. Rental prices are then used in creating weights for aggregation of the various asset-type capital stocks. Index number theory is then used to aggregate these stocks in a capital input measure. These issues will be examined in detail in Appendix 4.B.

4.3.1 The Domain of Definition of Capital

In its broadest sense, capital includes anything that involves foregoing 'something' in the present to earn returns in the future. It can include reproducible equipment and structures, land, inventories, financial assets such as stocks and bonds, 'human capital' acquired through education, training or experience, and finally intangibles such as software development costs, advertising expenses, or organizational efforts. Diewert (1980b, pp. 265-266) provides a discussion of the 'domain of definition of capital':

> *"What should be included in 'capital'? In the national accounting systems presently in use, capital consists of produced durable inputs. However, from the viewpoint of the theory of production, it is evident that natural resource stocks and land should also be included in the list of durable inputs. In addition, stocks of inventories and goods in process should be included. However, the practical problem here is how to obtain data on stocks of resources and inventories when it is not available in our current accounting framework."*

In the applied productivity literature, the items included from the list are usually limited to equipment, structures, land and inventories. The reason why these types of capital are included while others are omitted is related to the difficulty of measuring these items *in a manner consistent with the production model inherent in the System of National Accounts*.

Measurement difficulties seem to be the root cause of these exclusions. In the case of financial assets, many relevant data are often available. Furthermore, management of financial assets is essential to a firm's existence. However, it is difficult to identify a systematic relationship between decisions about financial assets and production decisions. By excluding financial assets, productivity economists have effectively regarded portfolio management as an 'investor' issue. Miller and Modigliani (1966) discussed the conditions under which production decisions could be seen as separable from decisions affecting the firms' financial portfolio.

Intangible capital assets are excluded for slightly different reasons. While intangible capital may play a more direct role in production than financial assets, they are excluded because there is greater difficulty in measuring their services. Since these assets are intangible, we cannot rely on tying the quantity of services to the quantity of goods. Computer software can be used to illustrate the problem. It is not only difficult to identify the capital services—it is equally difficult to identify the capital good.

Why are equipment, structures, inventories and land included? Equipment and structures are capital goods which are reproducible (unlike land) and depreciable (they lose value as they age). We can readily determine the cost of producing each unit of these types of capital and we can identify 'real quantities' by a) counting them and b) observing how they deteriorate over time.

Land, like equipment and structures, is a fixed asset that can be readily measured. It differs in that it is generally assumed not to depreciate. If anything this makes it simpler to account for. In his *Principles*, Ricardo described the rental market for a fixed supply

of land. While the total quantity of land may be fixed, land can be traded among sectors. Also, the characteristics of a plot of land from the standpoint of production can change, even if land itself is intrinsically the same. For example, development can occur nearby which may enhance the usefulness of the plot.

Inventories are goods and are therefore relatively easy to measure. However, the rationale for including inventories with capital is a bit less obvious to some observers since they are often not long-lived and do not resemble other assets in terms of durability. Goods held as inventories are often outputs (finished inventories) or inputs (purchased raw materials) of the firm. However, the same goods play a second role—that of capital—to the extent that firms deliberately maintain 'buffer stocks' of these goods to facilitate production. For example, raw materials are typically received in discrete batches, and significant amounts are stockpiled to protect against uncertainty over the timing of deliveries. Similarly, a firm stockpiles finished goods to ensure it can promptly fill new orders without excessive labour costs. In this sense, inventories play an important role in the production process and involve an opportunity cost that should be considered in the productivity measures.

4.3.2 Aggregation

4.3.2.1 Across Assets of Different Types

Once we have estimated capital stocks for various types of assets owned by an industry, we face the problem of aggregating these into a measure of total capital service input. We assume that capital services of each type of asset are proportional to its stock. Although the factors of proportionality are constant, the unit prices of capital are different for each type of stock.

We use these weights for aggregation rather than simply adding together the value of stocks (Appendix 4.B describes more formally the aggregation procedures used to arrive at the concept of capital services).

As indicated, capital theory comes into play on this issue. Property income R_{it} of industry i is the total rent received from the various assets a in each time period t

$$R_{it} = \sum_a c_{iat} K_{iat} \qquad (5)$$

where K_{iat} is the capital stock of the ath asset and c_{iat} is its rental price defined in equation (4). We already have estimates of the stocks and, as mentioned earlier, of property income. The latter are assembled from data on return on capital by industry from the input-output tables. These procedures ensure sets of rental prices that precisely account for each industry's property income.

In implementing these methods, we solve equations (4) and (5) for the 'ex-post' actual rate of return r_{it}.

This system of equations is solved with the data on capital stocks K_{at} and estimates of property income R_{it}. We solve this system of equations separately for each of 122 industries (1980 SIC) spanning the Canadian business sector. We compute stocks and rental prices for 28 different types of assets.

4.3.2.2 Across Industries of the Business Sector

Once we have measures of the capital service of industries, they can be used to construct measures of capital input growth for more aggregate sectors. In aggregating capital across industries, the weights we use are the industry's shares in the aggregate sector's property income. Since property income is a part of each industry's value added, it is additive across industries. Therefore the industry shares within a sector add up to one.

The use of property income in aggregating industry capital is consistent with its use as capital's share in industry multifactor productivity measurement and with its use as the total rental cost for the various assets deployed by the industry. It is also consistent with Domar's (1961) notion of an aggregate production model that has been derived from outputs and inputs of the various industries within the business sector.

Use of property income to construct weights for aggregation has certain implications. Investors in all industries may face similar ex-ante interest rates and capital may be allocated to industries in the long run in such a way that the rental price of a particular type of asset is the same in all industries. However, from the ex-post perspective, some industries earn higher rates of return than others do. By giving more weight to the industries earning higher returns, we are effectively saying that their assets are generating more capital services.

4.4 From Theory to Practice: Some Measurement Issues

A number of issues face empirical researchers who try to measure the various components of the user cost formula defined in equation (4). These issues are related to the considerable time and effort required for the construction of the tax variables included in the user cost formula and by the difficulties in getting accurate estimates on the expected capital gains term, the rate of return and the depreciation rate.

4.4.1 The Rate of Return

The rate of return the investor uses to discount future rents while making investment decisions is sometimes called the *ex-ante* rate of return. The *ex-ante* rate of return is the 'hurdle' rate of return used by firms as an investment decision rule. However, the rate r_{it} which we use reflects the property income actually realized and is called an *ex-post* rate of return. In order to rationalize its use, we have to assume that there is no difference between *ex-ante* and *ex-post* rates of return. However, in reality, expectations often are not met and the result is a difference between these two rates of return.

Berndt and Fuss (1986) and Hulten (1986) have discussed how the 'shadow price' of capital, computed from data on property income, is consistent with an *ex-post* rate of return. Fluctuations in capacity utilization manifest themselves as fluctuations in the shadow price of capital and in the *ex-post* rate of return. They argue that the appropriate weight for capital in multifactor productivity measurement is based on property income.

The lack of consensus concerning measurement of the nominal discount rate r in Jorgenson's rental price formula is illustrated by Diewert (1980a, pp. 476-477) as follows:

"Which r should be used? If the firm is a net borrower, then r should be the marginal cost of borrowing an additional dollar for one period, while if the firm is a net lender, then r should be the one-period interest rate it receives on its last loan. In practice, r is taken to be either (a) an exogenous bond rate that may or may not apply to the firm under consideration, or (b) an internal rate of return. I tend to use the first alternative, while ... Jorgenson and his co-workers used the second. As usual, neither alternative appears to be correct from the theoretical a priori point of view; so again, reasonable analysts could differ on which r to use in order to construct a capital aggregate."

4.4.1.1 The Internal Rate of Return

We begin with the internal nominal rate of return specification, developed in detail by Christensen and Jorgenson (1969), discussed in further detail by Fraumeni and Jorgenson (1980), and applied by the Bureau of Labor Statistics (BLS)(1983).

Combining equations (4) and (5), and assuming that the rate of return is the same for all assets but different across industries. The internal nominal rate of return r_t is

$$r_{it} = \frac{\left[R_{it} + \sum_{a=1}^{A} (-\delta_{ai} T_{it} q_{ait-1} K_{ait} + \Delta q_{ait} T_{it} K_{ait} + \phi_{it}\, q_{ait-1} K_{ait}) \right]}{\sum_{i=a}^{A} q_{ait-1} T_{it} K_{ait}}, \qquad (6)$$

where

$$\Delta q_{ait} \equiv q^{*}_{ait} - q_{ait-1} \text{ and } T_{iat} = \frac{1-u_{it} z_{iat} - k_{iat}}{1-u_{iat}}.$$

When property income becomes negative, this method is not capable of generating reasonable capital rental prices. In particular, the implied shadow price of capital is, in such cases, negative, implying that the firm is not covering its unit variable costs. While such a situation may be possible in theory, one would not expect to observe this in practice over long periods of time, for firms have the option to shut down in the short run if the price does not cover unit variable costs.

One way of obtaining 'reasonable' rental price measures in such cases is to remove from the underlying calculations the elements causing the large fluctuations. In most cases, these elements are the capital gains term or the capital compensation. The standard practice in the applied economics profession includes employing a before-tax constant nominal rate of return (Coen 1975) or an estimate of the real rate of return (between 3 and 4 percent) that is equal to the industrial average (Fraumeni and Jorgenson 1980).[7] In our case, the problem of negative capital compensation experienced by some industries during recession periods is eliminated by calculating a four-year moving average.

4.4.1.2 The External Rate of Return

Many researchers have finessed the idea on the existence of a unique rate of return by assuming perfect arbitrage between financial and real capital and between real capital

[7] A 3.5 percent constant real rate of return has been employed by the BLS (1983) in its multifactor productivity calculations for the agricultural sector, a sector in which capital compensation measures occasionally become negative.

of different types. In so doing, they are implicitly assuming that the real world is characterized by several closely related properties: a) that both the owners of real capital and business managers operate with perfect information; b) that physical capital is perfectly malleable and divisible; c) that incorrect capital formation decisions are easily reversible; d) that efficiently functioning used asset markets are readily available for all asset types; and e) that there is no divergence between the interests of corporate managers and the owners of corporate capital. If these conditions hold, then a unique (external or exogenous) rate of return can be used in the rental price calculation of all industries.

A number of studies of the user cost of capital have employed as a measure of the expected or *ex-ante* rate of return a bond yield taken from financial markets data. For U.S. studies, the most common are Moody rates for Aaa- or Baa-rated bonds, or long-term U.S. government bond yields (see Harper *et al.* 1989). In Canada, both the three-month Treasury Bill rate (McKenzie and Thompson 1997) and the long-term Canada bond rate (Harchaoui and Lasserre 1995) have been used. We refer to the specification of these rates of return as the external nominal rate of return model.

As an empirical alternative, therefore, we replace the nominal internal rate of return r_t in equation (4) with r_{ft}, the external nominal risk-free rate of return measured by market interest rates. Given the implied rental prices c_{ift} we recompute costs of capital for each asset as $c_{ift}K_{it}$, and then use $c_{Kt}K_t = \sum_{a=1}^{A} c_{ift}K_t$ to obtain new cost shares. Note that if this measure is used as an *ex-ante* measure of the cost of capital, unrealized expectations could result in a divergence between *ex-ante* and *ex-post* capital costs. As a measure of the implied 'surprise,' we take the ratio of actual capital compensation to the implied *ex-ante* capital compensation $\frac{R_t}{\sum_{i=1}^{N} c_{ift}K_t}$. This ratio can also be interpreted as the adjustment necessary to use the c_{ift} to apportion actual current capital compensation (see Harper *et al.* 1989).

However, many of the aforementioned conditions for the use of a single rate of return may not hold. For example, the perfect arbitrage argument probably breaks down because both the fixity and specificity of capital impede the capital stock adjustment process to changes in relative rates of return and limits the existence and the effectiveness of used asset markets as vehicles for correcting past capital-formation decisions. Further, the available evidence suggests that the interests of corporate management and stockholders are not always completely in accord (Myers and Majluf 1986). Whether or not deviations from these assumptions are serious is an empirical matter.

In the uncertain real world, different sources of financial capital have both different perceived risks and different costs. Debt is historically cheaper than equity and different industries incur different costs for externally raised capital. In fact, on this point, the available econometric evidence suggests that the use of industry-specific rates is an important key to obtaining well-behaved statements of production technology (Hazilla and Kopp 1984). Moreover, empirical studies suggest the existence and persistence of long run differences in rates of return at the firm level (Muller 1986) and industry level (Khemani and Shapiro 1990). As a result, it is our decision to use industry specific rates in our analysis.

It should be noted that alternate choices of the internal rate of return will affect the rates of growth of capital inputs only if they affect the relative weights that are applied to capital growth across industries. That is, it is not so much the mean level of the rate of return that matters as it is the relative values of the rate of return in calculating the weighted average of the rate of growth of capital over time. Using the internal rate of return provides a higher mean rate of return than does the long-term bond rate. But more importantly, it may give no greater weight in the index number formulae to different industries. To do so, it would have to be relatively higher in some industries than others.

4.4.2 Measuring the Capital Gain

The final refinement to the cost of capital estimation procedure involves the interpretation and measurement of the capital gain adjustment to the after-tax nominal cost of capital. Almost all formulations of industry rental prices found in the recent literature contain the expression—$r_{it} - \left(\frac{q^*_{iat} - q_{iat-1}}{q_{iat-1}}\right)$—defined to be the real after-tax opportunity cost of capital, where $\left(\frac{q^*_{iat} - q_{iat-1}}{q_{iat-1}}\right)$ is unambiguously defined as the 'inflation rate'. There are two questions that need to be resolved. First, what is the underlying assumption about expectations? Second, how do we measure capital gains?

In Jorgenson (1963, 1965) and in Hall and Jorgenson (1967), the expected capital gains term is set equal to zero since "*....we assume all capital gains are regarded as 'transitory'*" (Jorgenson 1963, page 249). In this case, the nominal and real rates of return are the same. Some argue that there is a defensible basis for making this assumption: Capital gains are not realized until an asset is sold. Thus, if most capital goods are held either a) to the end of their useful service lives or b) until obsolescence has effectively neutralized the potential gains, the term $\left(q^*_{iat} - q_{iat-1}\right)$ has no practical significance in the capital investment decision.

In Jorgenson and Siebert (1968a, b), two models are compared to the first assumption of 'transitory capital gains': One with perfectly anticipated capital gains where $q^*_{iat} = q_{iat}$ and the other where expectations are myopic and expected capital gains are zero, i.e., $q^*_{it} = q_{it-1}$. Empirical results reported by Jorgenson and Siebert indicate a modest preference for the former over the latter in explaining the investment behaviour of individual firms. It is perhaps in part for this reason that since the late 1960s, Jorgenson and his associates have only used the perfectly anticipated capital gains assumption in their empirical work on investment and productivity (see Jorgenson and Griliches 1967; Fraumeni and Jorgenson 1980; Jorgenson and Sullivan 1981 and Jorgenson and Fraumeni 1981).

As for the measurement of capital gains, Jorgenson and Siebert suggested three possibilities: a) the use of the consumer price index—the conventionally understood definition; b) the output price index of the industry; and c) the use of the price index for fixed assets used by the industry.

While appropriate for certain types of theoretical expositions, options a) and b) are of questionable value for industry-specific empirical studies on capital formation. In developing the arguments needed to implement the investment decision model, it is more

reasonable to assume that entrepreneurs formulate measures of the asset price inflation that they expect over the life of a contemplated investment. This is exactly what option c) suggests. A variant of option c) is to employ as an estimate of q^*_{it} a moving average of previous asset prices (Gillingham 1980). Both option c) and its variant will be investigated.

4.5. Analysis of the Results

This section discusses several alternate estimates of the user cost of capital c_{iat} and capital stock K_{iat} along with those of their different components.

4.5.1 The User Cost of Capital and Its Components

Economists have studied the cost of capital for the past four decades, but especially in recent years as a result of changes introduced in the Tax Act of 1981 and 1987 (Boadway and Kitchen 1999). Holding constant macroeconomic factors such as interest rates and expected inflation, the 1981 Tax Act lowered the cost of capital by introducing more accelerated depreciation. In a reversal of this policy, the 1986 Act lengthened tax lives and mandated straight-line recovery for structures. It also eliminated the investment tax credit, which had been available for all equipment and limited categories of structures.

Despite the interest of analysts on the effect of tax policy on capital costs, tax policy is not necessarily the only factor influencing expected capital costs. In a much-cited article in the United States, Bosworth (1985) noted that investment following the 1981-1982 recession was strongest in computers and automobiles, two categories not particularly advantaged by the 1981 tax reform. Bosworth concluded that prices of capital goods and movements in the cost of funds played a greater role in determining the cost of capital. More recently, Auerbach and Hassett (1991) found that investment in equipment was somewhat influenced by the Tax Reform Act of 1986, but that investment in structures did not appear to be affected by the revised tax provisions.

4.5.1.1 Tax Rates

Corporate income tax rates are captured through the component u_{it} of the user cost of capital. Until the substantial reduction under the 1986 Tax Reform Act, movements in the statutory corporate income tax rate were minor, thus having little influence on the cost of capital. The average corporate income tax rate for the business sector, shown in Figure 4.1, decreased from 49 percent during the 1961-1987 period to 44 percent during the 1987-2000 period. The average corporate income tax rate for the manufacturing sector followed a more pronounced downward trend between these two periods.

Figure 4.1 Average Corporate Income Tax Rate

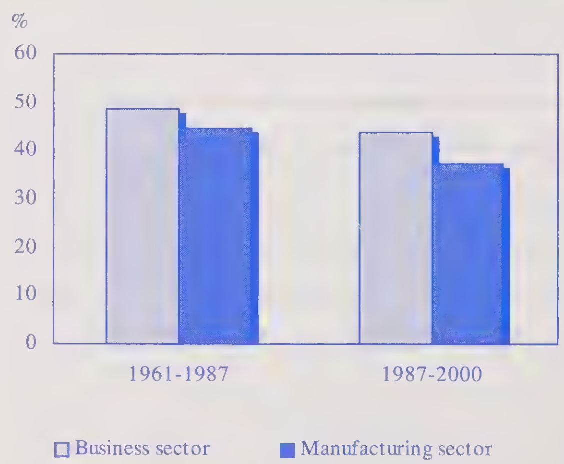
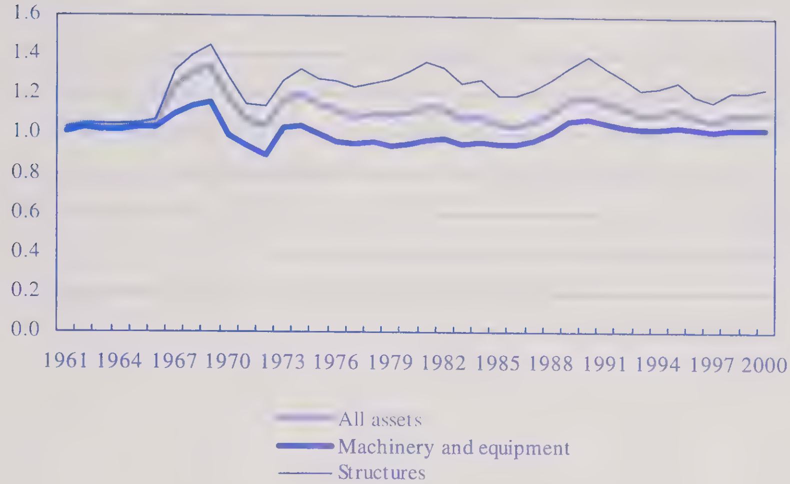


Figure 4.2 Tax Price, Manufacturing Sector



4.5.1.2 Tax Price

The variable $\left(\frac{1-u_{it}z_{iat}-k_{iat}}{1-u_{it}}\right)$, which represents the tax price of the asset, allows for the variation of income tax allowances according to different industries, asset types, and variations in allowances over time. Changes in corporate profit taxes over time are also allowed for. The tax price can be decomposed into two major components: First, the taxation of returns $\left(\frac{1}{1-u_{it}}\right)$; this component indicates that, as a result of the income tax rate u_{it}, to earn one dollar net of tax, capital must earn $\left(\frac{1}{1-u_{it}}\right)$ gross of tax. Second, the term $(1-u_{it}z_{iat}-k_{iat})$ indicates the effective reduction of the purchase price resulting from investment incentives. Some assets are eligible for an investment tax credit at rate k_{iat}. The variable z_{iat} represents the present discounted value of depreciation allowances per dollar of purchase price. These allowances are deductible from taxable income, thus saving the firm $u_{it}z_{iat}$ in tax obligations.

Corporate taxes aside, the provisions increase the after-tax returns on investment and lower the rental price of capital. A downward trend of the tax price can therefore be interpreted as a fiscal policy that promotes investment as it reduces the cost of capital, and vice versa for an upward trend.

Since tax price differs more across assets than industries, Figure 4.2 illustrates the effect of incentives on structures, machinery and equipment and all assets for the manufacturing sector. It is clear from Figure 4.2 that since the late 1980s, the tax price experienced a steady decline, albeit not in the same order of magnitude as the one that occurred in the early 1970s. The downward trend is steeper for structures in comparison to machinery and equipment.

Table 4.1 Components of the User Cost of Capital: Oil and Gas Industries

Year	Rental Price	Rate of Return	Depreciation	Capital Gains	Indirect Taxes
	c_{iat}	$T_{it} r_{it} q_{iat-1}$	$T_{it} \delta_{ia} q_{iat-1}$	$T_{it} \Delta q_{iat-1}$	$\phi_{iat}\ q_{iat-1}$
1961	0.03042	0.01925	0.01292	0.00195	0.00020
1962	0.02392	0.01616	0.01329	0.00589	0.00037
1963	0.02948	0.02076	0.01366	0.00535	0.00042
1964	0.03800	0.03614	0.01411	0.01262	0.00038
1965	0.04706	0.04007	0.01514	0.00855	0.00041
1966	0.02894	0.02421	0.01601	0.01174	0.00046
1967	0.05849	0.04094	0.02081	0.00394	0.00068
1968	0.03782	0.03411	0.02246	0.01964	0.00089
1969	0.04543	0.03586	0.02479	0.01639	0.00117
1970	0.04080	0.03394	0.02521	0.01971	0.00136
1971	0.06672	0.05984	0.02413	0.01847	0.00121
1972	0.07921	0.07930	0.02523	0.02672	0.00140
1973	0.06510	0.10201	0.02966	0.06834	0.00177
1974	0.08153	0.12083	0.03772	0.07961	0.00259
1975	0.11557	0.11912	0.04112	0.04846	0.00378
1976	0.13237	0.13078	0.04388	0.04716	0.00487
1977	0.14144	0.14705	0.04606	0.05566	0.00400
1978	0.16628	0.16851	0.05165	0.05934	0.00546
1979	0.12040	0.14231	0.05767	0.08359	0.00402
1980	0.13705	0.15625	0.06631	0.09054	0.00503
1981	0.11457	0.12915	0.07722	0.09873	0.00693
1982	0.08216	0.01645	0.08228	0.02720	0.01063
1983	0.13223	0.08270	0.07834	0.04128	0.01246
1984	0.15990	0.11310	0.08331	0.04488	0.00837
1985	0.19304	0.09050	0.08517	-0.01042	0.00696
1986	0.18190	0.13533	0.08425	0.04278	0.00510
1987	0.33303	0.25864	0.09069	0.02649	0.01019
1988	0.30727	0.24200	0.09455	0.03399	0.00471
1989	0.15830	0.08714	0.10101	0.03472	0.00487
1990	0.10229	0.08376	0.10455	0.09117	0.00514
1991	0.23613	0.16002	0.10639	0.03574	0.00546
1992	0.25215	0.17752	0.10474	0.03364	0.00352
1993	0.18845	0.13178	0.10264	0.05161	0.00564
1994	0.29913	0.18995	0.10876	0.00554	0.00595
1995	0.25627	0.12181	0.11298	-0.01585	0.00564
1996	0.21069	0.09980	0.10398	-0.00063	0.00628
1997	0.27132	0.16628	0.10035	0.00107	0.00576
1998	0.25024	0.13904	0.10577	-0.00021	0.00521
1999	0.28131	0.17073	0.10572	0.00000	0.00486
2000	0.29477	0.18213	0.10809	0.00000	0.00455
Mean	**0.14478**	**0.10763**	**0.06357**	**0.03064**	**0.00422**
Standard Deviation	**0.09353**	**0.06307**	**0.03660**	**0.03007**	**0.00302**

Note: Asset: Oil facility construction; c = rental price of capital; r = internal rate of return; q = price of the asset; T = tax price; δ = depreciation rate; ϕ = property tax rate.

4.5.1.3 Cost of Funds

The other term in the user cost of capital formula is the annual economic cost of using the asset. It consists of a real cost of funds $r_{it} - \frac{(q^*_{iat} - q_{iat-1})}{q_{iat-1}}$ plus the rate of economic depreciation for the asset δ. The cost of funds depends both on the risk premium required by financial markets and on how businesses finance their capital expenditures. Studies of the cost of capital have used different methodologies to measure this term, and no consensus has emerged on which method is most appropriate (Bosworth 1985).

This study applies the 3-5 year Canada bond rate and the internal rate of return from the Input-Output Tables to all assets and industries. The nominal internal rate of return is usually higher than the 3-5 year Canada bond rate as the former is a risk-adjusted rate of return. The higher volatility shown by the internal rate of return is indicative of the risk factor.

Movement in the rate of return tended to make investment less costly in the second half of the late 1960s and more costly in the 1980s. As indicated in Figure 4.3, the real rate of return $r_{it} - \frac{(q^*_{iat} - q_{iat-1})}{q_{iat-1}}$ was fairly level from the mid-1960s through the mid-1970s, and then rose sharply during the 1980s and the early 1990s. It remained high in the latter half of the early 1990s.

These changes tended to influence overall levels of investment: increases in the real rate of return blunted some of the stimulus to investment associated with the 1981 Tax Reform Act and reinforced the increased tax costs from the 1987 Act. They also may explain some of the shift away from structures observed during the late 1980s, since capital costs for long-lived assets are particularly sensitive to the cost of funds.

4.5.1.4 Estimates of the User Cost of Capital

We now examine the estimates of the rental price of capital c_{iat} defined in equation (4) and its components conveniently divided into four components:

a) the rate of return $T_{iat} r_{it} q_{iat-1}$;

b) depreciation $T_{iat} \delta_{ia} q_{iat-1}$;

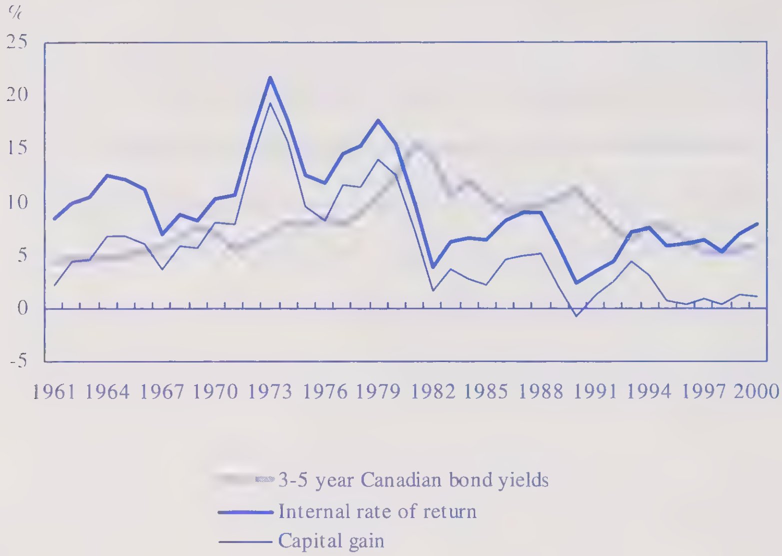
c) capital gains $T_{iat} \Delta q_{iat-1}$;

d) indirect taxes $\phi_{iat}\, q_{iat-1}$.

We illustrate the pattern of each of these components in Table 4.1 with oil facility construction used by oil and gas industries over the 1961-2000 period.

Substantial fluctuations occurred in the estimates of user cost, with large drops experienced in 1982 and during the 1989-1990 period. The fluctuations around trend experienced by the user cost of capital are largely attributable to the rate of return and, to a lesser extent, capital gains. The sharp drop in the rental price during these years is due to a substantial decline in the rate of return, largely reflecting the impact of the last two recessions on oil and gas industries.

Figure 4.3 Nominal Cost of Funds and Capital Gains



4.5.2 The Capital Stock Components: Produced Assets and Land

Recall that capital compensation as defined in equation (5) has two components: the rental price (or user cost) and the volume of the asset. The previous section described the trend in the user cost of capital and its major components. In the following section, we provide an overview of the methodology used to construct estimates of the volume of capital assets and an analysis of the results. The analysis is primarily focused on the components of produced capital stock estimates (i.e., the series, the initial capital stock and depreciation estimates) and land estimates, both of which represent the bulk of capital input estimates.

4.5.2.1 Produced Assets

Measurement of capital stock estimates in equation (2) are constructed by the use of a form of the perpetual inventory method. To construct a capital stock series, the analyst usually starts at some initial period zero with a measure of the initial capital stock K_o, and then calculates successive values of K_t by substituting the depreciation rate and the elements of an investment series into equation (2).

By successive backward substitution for K_{t-1} in equation (2), we can relate K_t directly to the initial capital stock value, K_o. K_t becomes a weighted sum of all past levels of investment and the depreciated value of the initial real capital stock

$$K_t = \sum_{j=0}^{t-1}(1-\delta)^j I_{t-i} + (1-\delta)^t K_0. \tag{7}$$

Measurement problems in the capital stock series may arise from any of the three components of equation (7): the I_t series, δ, or K_o.

Table 4.2 Business Sector's Estimates of the Initial Capital Stock for Machinery-Equipment and Structures

	β_o	β_K	γ	$\hat{K}_o \equiv \frac{\hat{\gamma}}{\hat{\beta}_K}$	R^2	Durbin-Watson
Machinery and Equipment	0.771	0.41	12.9	27.2	0.89	2.15
	(1.152)	(2.749)	(3.397)			
Structures	0.157	0.68	55.7	81.5	0.77	2.05
	(0.774)	(1.924)	(2.214)			

t-statistics in parentheses.

4.5.2.1.1 Initial Capital Stock

Various methods have been used to estimate the initial capital stock K_o, but virtually all researchers acknowledge that the starting values are subject to errors. As a result, where at all possible, they have chosen starting dates for the capital stock calculation 10, 20 or more years before the beginning of the estimation period—relying on the implication of equation (7) that the impact of K_o on subsequent values of the capital stock decays exponentially. In this section, we propose an alternative approach to the construction of the initial capital stock.

Consider the following production function under constant returns to scale

$$\ell nQ_t = \beta_o + \beta_K K_t + (1-\beta_K)\ell nL_t + \varepsilon_t \tag{8}$$

where Q_t, K_t and L_t are real output, capital stock and the number of hours worked, respectively. Output and labour are both expressed in log form; β_o and β_K are the unknown parameters and ε_t is an independently distributed random error. Substitute the alternative definition of capital stock $K_t = \tilde{I}_t + (1-\delta)^t K_0$, where $\tilde{I}_t \equiv \sum_{j=0}^{t-1}(1-\delta)^j I_{t-i}$ is the weighted sum of past investments, in equation (8), we get

$$\ell n\left(\frac{Q_t}{L_t}\right) = \beta_o + \beta_K\left(\tilde{I}_t - \ell nL_t\right) + \gamma D_t + \varepsilon_t \tag{9}$$

where $\gamma \equiv \beta_K K_o$ is a constant like any other parameter in equation (9) and $D_t \equiv (1-\beta)^t$.

The estimation of equation (9) gives the parameter estimates $\hat{\beta}_K, \hat{\gamma}$ and, therefore, $\hat{K}_o \equiv \frac{\hat{\gamma}}{\hat{\beta}_K}$. Using the generalized least square method, the model (9) was separately estimated for machinery and equipment and structures as these two capital asset types have a different impact on the business sector's labour productivity level in equation (9). The results shown in Table 4.2 indicate the parameters β_K and γ are both positive and significant at 5% level of significance. The model shows no evidence of spurious

Table 4.3 Contribution of Business Sector Industries to the Growth of Information Technology Real Investment (Percentage)

	1981-2000	1981-1988	1988-2000
Agriculture	0.4509	0.0225	0.7031
Fishing and Trapping	0.0092	0.0031	0.0150
Logging and Forestry	0.0385	0.0601	0.0295
Mining	0.1771	0.1562	0.2093
Crude Petroleum and Natural Gas	0.2325	0.1683	0.2715
Quarry and Sand Pit	0.0207	0.0224	0.0202
Services Incidental to Mineral Extraction	0.1242	0.1055	0.1439
Food	1.0151	0.7245	1.1357
Beverage	0.2928	0.2202	0.3219
Tobacco Products	0.1294	0.0507	0.1730
Rubber Products	0.2080	0.2566	0.1840
Plastic products	0.2817	0.3543	0.2299
Leather and Allied Products	0.0251	0.0366	0.0150
Primary Textile	0.0585	0.0956	0.0370
Textile Products	0.0300	0.0560	0.0110
Clothing	0.1934	0.1749	0.2210
Wood	0.2979	0.2687	0.3098
Furniture and Fixture	0.1210	0.0922	0.1304
Paper and Allied Products	0.7127	0.7829	0.7246
Printing, Publishing and Allied	0.9452	0.4226	1.2155
Primary Metal	0.9990	1.5687	0.7972
Fabricated Metal Products	0.4534	0.7070	0.2818
Machinery (Except Electrical Machinery)	0.5470	0.4389	0.5641
Aircraft and Aircraft Parts Industry	0.1558	0.1984	0.1210
Transportation Equipment	1.1444	1.7276	0.7195
Electrical Products	0.7428	0.9302	0.6083
Communication and Electronic Equipment	0.9927	1.2863	0.7686
Office, Store and Business Machines	0.4360	0.6481	0.3185
Non-metallic Mineral Products	0.1614	0.2589	0.1454
Refined Petroleum and Coal Products	0.3511	0.4019	0.3129
Chemical and Chemical Products	0.9916	0.8772	1.0832
Pharmaceutical and Medicine	0.1468	0.1497	0.1517
Other Manufacturing	0.5542	0.5553	0.5160
Construction	1.4228	1.7266	1.3120
Transportation	2.6414	1.9618	2.8221
Pipeline Transport	0.3343	0.1201	0.4530
Storage and Warehousing	0.1023	0.0604	0.1164
Communication	14.2605	10.2797	17.7388
Other utility	6.0068	8.1463	4.5614
Wholesale Trade	5.4526	3.2239	6.6863
Retail Trade	6.4985	4.1563	7.8001
Finance and Real Estate	22.5765	21.3661	22.6004
Insurance	1.6581	2.5720	1.0207
Business Services	10.9975	9.3444	11.9040
Educational Service	0.1659	0.2637	0.1108
Health and Social Service	0.6868	0.8744	0.5974
Accommodation and Food Services	1.8002	3.4771	0.8834
Amusement and Recreational Services	1.1296	1.5759	0.8646
Personal and Household Services	0.1860	0.3413	0.1115
Other Services	11.0400	16.6880	7.9278
Total	**100.0000**	**100.0000**	**100.0000**

correlation as indicated by a reasonably high level of the R^2 (a maximum of 0.87) and the estimates of the initial capital stock, evaluated at 81.5 and 27.2 billion of 1961 dollars, are statistically significant. These estimates were then allocated by industry and asset categories according to the 1961 investment series.

4.5.2.1.2 Investment

The composition of business investment in Canada changed dramatically during the last two decades. Workplaces were transformed as a result of investments in information technology equipment, such as computers, software and communications equipment (see Chapter 1). Businesses built new office towers and shopping malls, but few industrial facilities. These changes are reflected in the contribution of information technology, other machinery and equipment and structures to the change in aggregate investment during the last two decades as well as in the contribution of each industry to the growth of aggregate investment.

As shown by Figure 4.4, the contribution of information technology equipment to the increase in real investment has risen significantly. This category accounted for 28 percent of the growth of total real business investment during the 1981-1988 period. During the 1988-2000 period, its contribution increased sharply, contributing 34 percent of real total business investment growth. A similar increase was experienced by the contribution of structures to real business sector investment between these two periods, while the contribution of other machinery and equipment declined sharply.

Figure 4.4 Average Contribution of Asset Classes to Business Sector Investment Growth

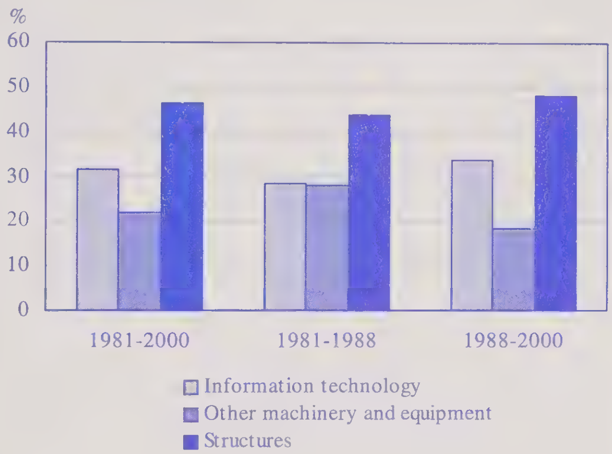


Table 4.3 shows the contribution of different industries to business sector real investment in information technology between 1981 and 2000. Three industries alone—communication, finance and real estate and business services—have contributed about 41 percent of the growth in information technology real investment during the 1980s. This contribution jumped to 52 percent in the 1990s, primarily as a result of the shift in the contribution of communication industries. Amongst the other major industries that saw their contribution increase during these two periods are wholesale (from 3.2 percent to 6.7 percent) and retail trade industries (from 4.2 percent to 7.8 percent), while the contribution of finance, insurance and real estate and business service industries increased only moderately.

4.5.2.1.3 Depreciation

In the perpetual inventory method, the pattern of depreciation for a given asset is determined by its 'depreciation profile.' The depreciation profile for a given type of asset describes the pattern of how, in the absence of inflation, the price of an asset of that type declines as it ages. The methodology used by the productivity program for estimating

Figure 4.5 Distribution of Inventories by Major Sectors (Current Prices)

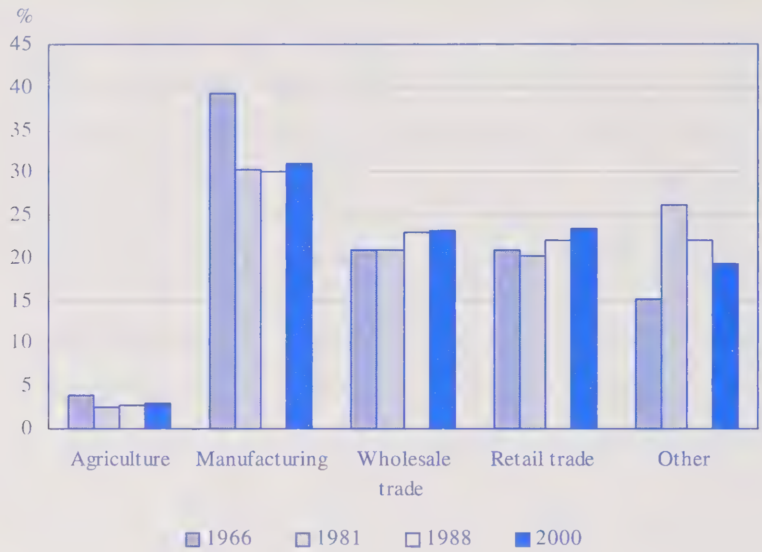


Figure 4.6 Inventories in Constant Prices

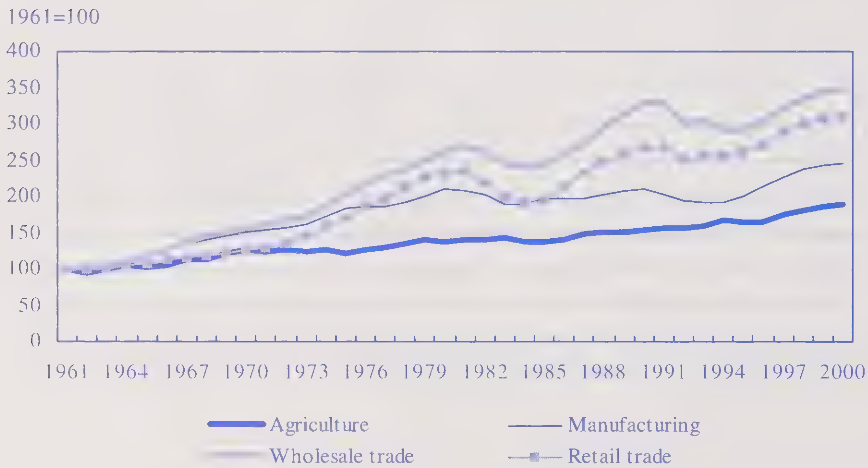
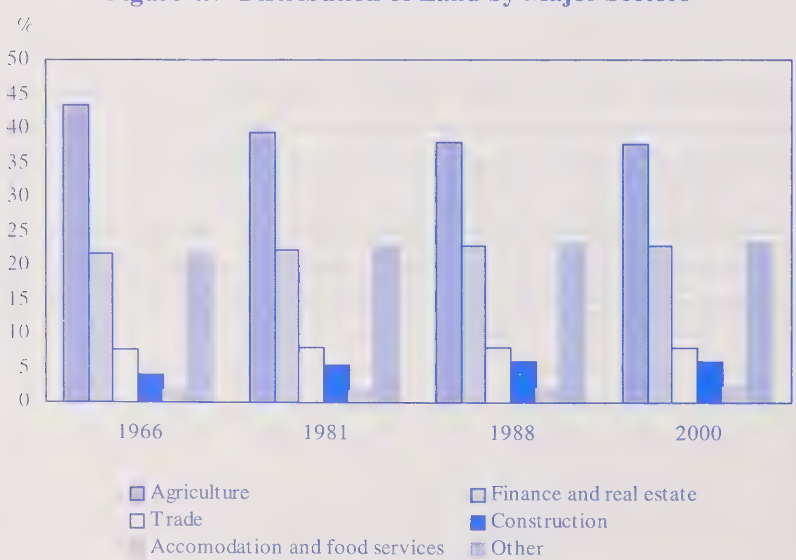


Figure 4.7 Distribution of Land by Major Sectors



depreciation is based on a maximum likelihood survival model that produces econometric estimation of depreciation rates (see Chapter 2).

The profile for 28 types of assets used by different industries is estimated using a rich dataset of used asset prices that includes information on retirement. The results suggest that, in general, depreciation profiles are consistent with the geometric pattern of price declines. Consequently, in the estimates used to construct capital stock estimates, the depreciation profiles for most assets were assumed to be strictly geometric.

The geometric depreciation rates used by Statistics Canada's productivity program to derive the estimates of net stocks and depreciation for 19 non-residential assets are shown in Table 4.4. As one may expect, the depreciation rates are particularly high for computers (51 percent) and communication equipment (20 percent); they are low for buildings (7 percent). Other structure-type assets, such as road, highway and airport runway construction, electric power, dams and irrigation construction, and gas and oil facility construction, display depreciation rates of 10, 6 and 8 percent, respectively).

In the case of roads, highways, dams and irrigation, their high depreciation rates partly reflect the impact of the difficult Canadian winter climate. As for gas and oil facility construction assets, the high depreciation rate reflects to a large extent the irreversibility effect[8]. In mining industries, investment expenditures are sunk costs because they are often firm or even plant specific. An oil and gas facility cannot be used in the copper, asbestos or in any other mineral industry, as the technology is specific to the type of mineral extracted. Because the resale value of the asset is small even though it has been in use for a short period of time, these sorts of assets experience fast depreciation rates on used asset markets.

4.5.2.1.4 Inventories

A treatment of inventories that is suitable for productivity measurement can be found in Diewert and Smith (1994). We follow their treatment of inventories in our multifactor productivity estimates. Since there is no investment tax credit, discounted value of depreciation allowances, or economic depreciation, the user cost formula (4) simplifies to

$$c_{iat} = q_{iat-1}\left(\frac{\left[r_t - \dfrac{\left(q^*_{iat} - q_{iat-1}\right)}{q_{iat-1}}\right]}{1-u_{it}}\right)$$

Figure 4.5 shows that in 2000, more than three-quarters of inventories are distributed between manufacturing and trade industries, down from 81 percent in 1966. Over the 1966-2000 period, manufacturing experienced a decline in its share of inventories to the benefit of trade industries who posted the highest average annual growth rate (Figure 4.6).

[8] Irreversibility is nowhere as obvious as in the mining sector where the equipment is bulky and even ore specific. In a recent paper, Harchaoui and Lasserre (2001) formulated and tested a model of investment under irreversibility using an option pricing framework. The evidence suggested that, for a sample of Canadian mines during the 1960-1980 period, the hypothesis of irreversibility cannot be rejected at a high level of significance. For a general discussion on the importance of irreversibility, see Dixit and Pindyck (1994).

Table 4.4 Geometric Depreciation Rates by Asset for Non-residential Capital Stock

Assets	Median Depreciation Rate
Office Furniture, Furnishing	0.33
Computers and Office Equipments	0.51
Household and Services Machinery and Equipment	0.14
Electrical Industrial Machinery and Equipment	0.19
Non-electrical Industrial Machinery and Equipment	0.22
Industrial Containers	0.05
Conveyors and Industrial Trucks	0.18
Automobiles and Buses	0.20
Trucks (excluding industrial trucks) and Trailers	0.20
Locomotives, Ships and Boats and Major Replacement Parts	0.12
Aircraft, Aircraft Engines and Other Major Replacement Parts	0.06
Communication Equipments	0.20
Other Equipments	0.20
Non-residential Building Construction	0.07
Road, Highway and Airport Runway Construction	0.10
Gas and Oil Facility Construction	0.08
Electric Power, Dams and Irrigation Construction	0.06
Railway and Telecommunications Construction	0.10
Other Engineering Construction	0.08
Total Non-residential Capital Stock	**0.14**

4.5.2.2 Land

Like subsoil and timber assets in the case of mineral industries, land is a key input in the agriculture sector which accounts for about 38 percent of land use by the business sector in Canada in 2000, down from 43 percent in 1966 (Figure 4.7). However, a number of unique attributes set land apart from other resources. First, land is generally not a depletable asset; therefore it does not depreciate over time. Second, location is key in determining the use of land. Third, the total stock of land is, for all intents and purposes, fixed. Since in many productivity studies, land is held fixed, it is often neglected as an input into production. However, even though the quantity of land is fixed, its quality-adjusted measure is not and so neglecting land can have an effect on aggregate input growth.

The approach used in the construction of the stock of land is strictly analogous to the approach taken for data on capital or labour input. Land services represent the quantity of land input, just as capital services represent the quantity of capital input. Measures of land services are derived by representing the stock of land at each point of time as a weighted sum of various categories of the stock of land (by province). Rental rates for land services provide the basis for property compensation, just as wage rates provide the basis for labour compensation. Data on rent is available in a readily accessible form only for the portion of agricultural land engaged in an active rental market. However, rental value of other agricultural land types can be imputed on the basis of the estimates of land by type of tenure and property compensation for the rented land.

The construction of a revised index of real land input has to divide the value of land services between price and quantity with price corresponding to the rental rate and quantity as the amount of land services utilized. This division is precisely analogous to the separation of the value of labour services between a wage rate and the quantity of labour services.

Agriculture data provide information on the volume of land and rental prices classified according to various characteristics such as the province, farm size and types of farms. The quality-adjusted stock of agricultural land was estimated using the assumption that the bulk of the heterogeneity in the quality of land can be captured through the provincial dimension. Other dimensions such as the type of farms may also introduce additional heterogeneity but were ignored at this point for the sake of simplicity.

Data on total area of farms were collected by province for the 1961 to1996 period using the Census of Agriculture. The concept of total area of farms encompasses all categories of land that enter into the activities of farms. This includes improved land (such as land under crop, pasture, summer fallow and other improved land) and unimproved land (woodland and other unimproved land).

The value of rent, available only for land that is leased or rented, covers roughly 30 percent of the total area of farms in Canada. Rent includes cash rent gross of taxes and share rent. For property such as land with an active rental market the separation may be carried out by means of market data on rental rates and corresponding data on the tenure of land. This method may be extended from rental property to property utilized by its owners if rental market values reflect the implicit rentals paid by owners for the use of their property. An imputation of this type is employed in the Canadian System of National Accounts in the measurement of services of owner-occupied housing. A precisely analogous imputation occurs in measuring labour services of the self-employed. The assumption that within the same province the competitive process ensures that the rental price of an acre of land is identical for leased or owned land was used to estimate the value of rent for the whole area of farms in Canada.

The following steps outline the procedure used to arrive at the Fisher Ideal Index of the quality adjusted stock of agricultural land:

1) $L_{i,j,t}$ is the total area of farms by tenure type $i = o, r$ (owned vs. rented) and by province j in year t;

2) $R_{r,j,t}$ is the total value of rent, which includes the rent paid in cash (cash rent) and on a share crop basis (share rent) for land and buildings rented from the government or private sector, including other farmers. The cash rent includes the taxes paid on property rented from others;

3) The rental price of one acre of rented land is:

$$c_{r,j,t} = \frac{R_{r,j,t}}{L_{r,j,t}}$$

and is assumed to be identical to the rental price of owned rent:

$$c_{r,j,t} \equiv c_{j,t}$$

4) The quality adjusted index of agricultural land $\tilde{L}_{t,t-1}$ between two adjacent periods is a Fisher (F) chained index defined as a weighted average of the index of the provincial area of farms between t and $t-1$, that is

$$\tilde{L}^{F}_{t/t-1} = \left(\tilde{L}^{L}_{t/t-1} \times \tilde{L}^{P}_{t/t-1}\right)^{\frac{1}{2}}$$

where

$$\tilde{L}^{L}_{t/t-1} = \sum_{j=1}^{10} \left(\frac{L_{j,t}}{L_{j,t-1}} \right) \left(\frac{c_{j,t-1} \cdot L_{j,t-1}}{\sum_{j=1}^{I} c_{j,t-1} \cdot L_{j,t-1}} \right) \text{ and}$$

$$\tilde{L}^{P}_{t/t-1} = \sum_{j=1}^{12} \left(\frac{L_{j,t}}{L_{j,t-1}} \right) \left(\frac{c_{j,t} \cdot L_{j,t-1}}{\sum_{j=1}^{12} c_{j,t} \cdot L_{i,t-1}} \right).$$

The construction of non-agricultural land in constant and current prices over the 1961-1997 period required various steps. We begin with the business sector's estimates for area of land available on a quenquennial basis from Statistics Canada's environmental accounts. Estimates of non-agricultural land were then derived as the difference between the area of business sector land and that used up by the agriculture sector. These estimates are then broken down by industry using the information on property taxes available from the Input-Output Tables to obtain the area of land by industry. Estimates of land in current prices are derived as follows: First, book value industry estimates of non-agricultural land were derived from corporate balance sheets produced by the Industrial Organization and Finance Division of Statistics Canada. These estimates were then turned into current price estimates using the ratio of current value to book value of non-agricultural land, respectively available from the National Balance Sheet Accounts and corporate balance sheet accounts.

Once a stock is estimated for land, a user cost equation similar to equation (4) is estimated for each asset in each ownership sector. Since there is no investment tax credit, discounted value of depreciation allowances, or economic depreciation, the user cost equation simplifies to:

$$c_{iat} = q_{iat-1} \left(\frac{\left[r_t - \frac{\left(q^{*}_{iat} - q_{iat-1}\right)}{q_{iat-1}} \right]}{1 - u_{it}} + \phi_{it} \right)$$

4.5.3 Measurement of the Effect of Changing Capital Composition under Alternate Estimates of the User Cost of Capital

4.5.3.1 On Capital Composition Effect

The growth of capital input under assumptions of heterogeneity is derived from an index that weights the growth in capital for different assets and industries by the rental price of capital, or more appropriately, by the share of that asset/industry class in the total capital cost. As such, this index can differ from an index that is just derived from the unweighted growth in the value of all assets. It will be higher than the latter to the extent that growth is coming mainly in those asset classes that have a relatively high rental cost of capital—either those in risky, higher return industries, or in assets with high rates of depreciation, i.e., computers. The difference between the growth of capital stock that weights different assets by relative unit capital costs and the growth in capital that is derived by assuming all assets provide the same capital services per dollar of assets measures the effect of the changing composition of capital—sometime referred to as the effect of changes in quality of capital.

We compare and evaluate the composition effect under five alternate capital rental price formulae discussed in Section 4.4. Once estimates of rental prices c_{iat} and capital stocks K_{iat} at the asset level are separately measured, they are used to construct series on capital services $\tilde{K}_{it}$ using a chain Fisher index for the industry i, the asset a and two adjacent periods t and $t-1$ (see Appendix 4.B for details):

$$\tilde{K}^{F}_{i,t/t-1} = \left(\tilde{K}^{L}_{i,t/t-1} \times \tilde{K}^{P}_{i,t/t-1}\right)^{\frac{1}{2}}, \tag{10}$$

where $\tilde{K}^{L}_{i.t/t-1}$ and $\tilde{K}^{P}_{i.t/t-1}$, the Laspeyres and Paasche indices of capital services respectively, are defined as follows:

$$\tilde{K}^{L}_{i,t/t-1} = \frac{\sum_{a=1}^{A}\left(\frac{K_{iat}}{K_{iat-1}}\right)c_{iat-1}K_{iat-1}}{\sum_{a=1}^{A}c_{iat-1}K_{iat-1}} \quad \text{and} \quad \tilde{K}^{P}_{i,t/t-1} = \frac{\sum_{a=1}^{A}\left(\frac{K_{iat}}{K_{iat-1}}\right)c_{iat}K_{iat-1}}{\sum_{a=1}^{A}c_{iat}K_{iat-1}}. \tag{11}$$

Equations (10) and (11), which demonstrate the important role of the rental price of capital in capital services aggregation estimates, have the following heuristic interpretation: the change in aggregate capital service flow is a weighted sum of the change in the a asset-specific capital stock, where the weights are defined in terms of the rental cost of capital.

This aggregation of capital services weights each type of capital by its relative rental cost share, and should be distinguished from the direct summation of capital stock defined as

$$K_{it} = \sum_{a=1}^{A} \bar{K}_{iat} \,. \tag{12}$$

The capital composition effect defined as $\frac{\tilde{K}_{it}}{\bar{K}_{it}}$ (see equations (10) and (12) above) captures the extent to which capital mix shifted toward shorter-lived equipment and away from structures and land.

The composition of capital changed over the years as investment in shorter-lived equipment contributed to the growth of aggregate investment than longer-lived structures (see Table 4.3). Because depreciation rates δ for equipment are larger than for structures (Table 4.4) and capital gains $\left(\frac{q_{iat}-q_{iat-1}}{q_{iat-1}}\right)$ are smaller for equipment than for structures, it is clear that, *ceteris paribus*, the rental price of equipment (e), c_{iet}, will be larger than the rental price of structures (s), c_{ist}. Intuitively, this means that because of the shorter life of equipment, investors require more services per year from a given dollar of investment in equipment than in structures. Accordingly, the growth of equipment will be weighted more heavily than growth in structures. And because the former grew more quickly than the latter, the aggregate capital services computed from equation (10) will grow more quickly than aggregate capital calculated as mere summation as indicated by equation (12).

4.5.3.2 Estimates of the Capital Composition Effect

The alternate user cost approaches used to derive capital services are described in Table 4.5. The five alternative approaches are all motivated either by conceptual arguments or their use in the economic literature. Given the assumptions underlying the standard multifactor productivity framework, we favour approaches 1, 2, and 3. That is, since the standard estimates presume constant returns to scale, it is appropriate to assume that the factor share earned by capital is the surplus that is measured in national accounts. After the U.S. experience, we adopt the assumption of perfect anticipations but test to see whether a moving average estimator makes much difference.

Table 4.6 presents estimates of the average annual growth rate and the volatility (standard deviation of the annual growth rate) of the composition effect for the business sector and its major constituent subsectors over the 1961-2000 period. Several results are worth noting. First, at the business sector level, the approaches 2, 4.1 and 4.2 all display the same order of size of the composition effect (roughly 1.2 percent in terms of average annual growth rate). So, imposing the identity between nominal output and total costs when the external rate of return has been used does not alter the estimate of capital composition (approach 4.1 vs. approach 4.2), but it does increase its volatility in a significant way. The approaches 1 and 3, on the other hand, provide similar average annual growth of capital composition but capital composition has a significantly lower level of volatility under the approach 1.

The composition effect reflects a) the long-term historical shift toward equipment and away from structures and b) the long-term tendency for the prices of new structures to rise more rapidly than those for equipment, causing the capital gains term subtracted in the structures rental price to be larger than that subtracted in the equipment rental price (recall that this term is omitted from the approach 2). This latter effect accentuates the

Table 4.5 Summary of Alternative Approaches of the User Cost of Capital

	Reference	Characteristics: Rate of Return	Characteristics: Capital Gains
Approach 1	Jorgenson-Siebert (1968a); Christensen-Jorgenson (1969); Fraumeni-Jorgenson (1980); BLS (1983)[a]	Internal Nominal Rate of Return from Capital Compensation Identity	Perfect Anticipations $q^*_{ait} = q_{ait}$, i.e perfectly Anticipated Capital Gains
Approach 2	Jorgenson-Siebert (1968b)	Internal Nominal Rate of Return from Capital Compensation Identity	Myopic Anticipations $q^*_{ait} = q_{ait-1}$, i.e. zero Expected Capital Gains
Approach 3	Gillingham (1980)	Internal Nominal Rate of Return from Capital Compensation Identity	Perfect Anticipations; Estimate of q^*_{ait} Using a Moving Average of Previous Asset Prices
Approach 4.1	Coen (1975); McKenzie and Thompson (1997)	External Nominal Risk Adjusted Rate of Return: the Identity Between the *ex ante* and *ex post* Rate of Returns is Not Maintained	Perfect Anticipations $q^*_{ait} = q_{ait}$, i.e. Perfectly Realized Capital Gains
Approach 4.2		External Nominal Risk Adjusted Rate of Return: the Identity Between the *ex ante* and *ex post* Rate of Returns is Maintained	Perfect Anticipations $q^*_{ait} = q_{ait}$, i.e. Perfectly Realized Capital Gains

Notes: [a] except agriculture

existing difference between equipment and structures rental prices as a result of higher economic depreciation of equipment, and thereby results in a larger rental price and cost share weight for the more rapidly growing equipment services component.

Although the estimation of the composition effect under alternate models of the user cost of capital is useful in its own right, the question on the extent to which differences in these various estimates are statistically significant still remains open. This question is addressed through the estimation of a regression model in which the dependent variable is the index of the composition effect and the right-hand variables are dummy variables for the approaches 2, 3, 4.1 and 4.2, time dummy variables for the 1961-2000 period, and interaction terms between each model and each time dummy variable. We used a fixed effect model based on a data set consisting of 16 industries, 5 approaches, and 39 years.

The results (not reported here because of the number of parameter estimates involved) indicate that statistically significant differences exist between the approach 1 and the approaches 2 and 4.2, particularly during the post 1981 period. But the level of uncertainty associated with these differences is relatively high (the parameter is significant only at 10 percent of significance). Given this result and the fact that the approaches 2 and 3 rely on stringent assumptions (a unique rate of return for the whole business sector under the approach 2 and the nominal rate of return is identical to the real rate of return under the approach 3), we adopt approaches 1 and 3 as the preferred routes on both theoretical and empirical grounds. Alternative 1 is now reported as part of the multifactor productivity program. It should be noted that this measure is also most closely related conceptually to the estimates produced by the BLS.

Table 4.6 Comparison of the Alternative Approaches of Capital Composition: Business Sector

	Approach 1		Approach 2		Approach 3		Approach 4.1		Approach 4.2	
	AAGR	Vol	AAGR	Vol	AAGR	Vol	AAGR	Vol	AAGR	Vol
Agricultural and Related Services	-0.995	0.034	-0.396	0.029	-1.057	0.036	-0.812	0.032	-0.209	0.033
Fishing and Trapping	-0.457	0.008	0.222	0.011	-0.474	0.008	-0.589	0.008	-1.027	0.014
Logging and Forestry	-0.110	0.012	-0.366	0.020	-0.156	0.013	0.095	0.012	0.181	0.026
Mining, Quarrying and Oil Well	0.145	0.007	0.479	0.006	0.225	0.007	0.234	0.006	0.212	0.010
Manufacturing	0.976	0.011	1.158	0.016	0.931	0.010	1.110	0.010	1.321	0.018
Construction	0.429	0.016	1.816	0.024	0.587	0.015	0.473	0.012	0.615	0.022
Transportation and Storage	1.629	0.011	1.158	0.012	1.782	0.011	1.473	0.011	1.362	0.014
Communication and Other Utility	1.017	0.011	0.304	0.005	1.050	0.012	1.103	0.011	0.875	0.011
Wholesale Trade	1.044	0.010	2.772	0.033	1.043	0.010	1.194	0.011	1.799	0.021
Retail Trade	1.839	0.014	1.908	0.025	1.737	0.014	1.574	0.013	1.198	0.011
Finance, Insurance and Real Estate	1.026	0.013	0.950	0.030	0.954	0.014	0.878	0.012	0.678	0.023
Business Service	1.026	0.023	2.280	0.041	1.154	0.023	1.078	0.015	2.041	0.052
Educational Service Industries	5.363	0.042	0.239	0.020	4.737	0.039	5.307	0.051	0.794	0.030
Health and Social Service	0.316	0.012	-0.013	0.026	0.304	0.012	0.397	0.009	0.813	0.029
Accommodation and Food Services	0.717	0.010	0.477	0.034	0.550	0.009	0.756	0.010	0.772	0.036
Other Service	2.121	0.022	-0.315	0.019	2.120	0.022	2.065	0.023	1.650	0.032
Business Sector	**1.16**	**0.007**	**1.242**	**0.013**	**1.167**	**0.007**	**1.202**	**0.007**	**1.229**	**0.014**

Notes. AAGR = Average annual growth rate over the 1981-2000 period; Vol = Volatility (the volatility is measured as the standard-deviation of the year-to-year growth rate of the user cost of capital);
Approach 1: internal nominal rate of return from capital compensation identity and perfectly realized capital gains;
Approach 2: internal nominal rate of return from capital compensation identity and zero expected capital gains;
Approach 3: internal nominal rate of return from capital compensation identity and expected by the moving average of previous asset prices;
Approach 4.1: external nominal risk-adjusted rate of return, perfectly realized capital gains and the identity between the *ex-ante* and *ex-post* rate of returns is not maintained;
Approach 4.2: external nominal risk-adjusted rate of return and perfectly realized capital gains, but the identity between the *ex-ante* and *ex-post* rate of returns is maintained.

4.6 Concluding Remarks

Statistics Canada started to produce multifactor productivity estimates in the late eighties. These estimates rely on a simple measure of capital services that aggregates the dollar value of all forms of capital, giving equal weights to the dollar value of all assets. This chapter explores the extent to which a more complex concept of capital services—one that recognizes asset heterogeneity—can be implemented. It has discussed the following points: a) the underpinnings of the concept of capital services and the domain of definition of capital, b) the alternate rental price of capital formula, c) the empirical analysis of these formulae along with their impact on capital composition.

An important conclusion reached by this study is that there are numerical differences in the alternate user cost formulae that are the prime candidates for adoption—but they are not statistically significant. On both empirical and conceptual grounds, the program has chosen the approach based on the internal rate of return and perfect or adaptive expectations.

The complex procedure of estimating capital service input taking into account asset heterogeneity makes a significant difference in the empirical assessment of the role of capital in the Canadian business sector's economic growth. The growth rate of a traditional capital stock measure (the directly aggregated real stock of wealth) for the Canadian business sector from 1981-2000 was 2.8 percent per year. However, capital services (based on the approach 1) grew 3.4 percent for the same period. This implies that capital services have grown 21 percent more than the capital stock. The main source of this difference is a long-term trend in the proportion of the capital stock accounted for by service-intensive short-lived equipment. This change in the measurement technique then accounts for a larger proportion of total growth than did the simple measure of capital measure.[9]

The implementation of the concept of capital services in Statistics Canada's multifactor productivity program constitutes a major step forward for Canada-U.S. comparisons of productivity growth. Using comparable methodologies underlying the estimates of output and inputs, Table 4.7 contains a breakdown of the growth of labour productivity into three components. The first arises from capital deepening—the increase in capital available per worker. The second comes from changes in the composition of the workforce—from increases in the skills of workers. The third is a residual—what is referred to as multifactor productivity. The latter captures increases in output that cannot be attributed to increases in labour or capital and captures all improvements in the production process that come from improvements in organization, more complete exploitation of economies of scale, and externalities that arise both from general improvements in knowledge and specific spillovers that allow for more efficient plant operations.

From 1981 to 2000, output per hour grew at an annual rate of 1.4% in the Canadian business sector (1.9% in the U.S.). Of the 1.4% growth rate in labour productivity in Canada, 0.3 percentage points are attributed to increases in multifactor productivity (0.9 percentage points for the U.S.), 0.6 percentage points to the contribution of capital deepening (0.7 percentage points for the U.S.) and 0.5 percentage points to changes in labour composition (0.3 percentage points for the U.S.). The contribution of capital deepening is composed of the contribution of information technology equipment, the contribution of other machinery and equipment and structures (which include inventories and land). In both Canada and the United States, most of the impact of capital

[9] Data on output prior to 1981 were not available at the time this chapter was written.

Table 4.7 Compound Average Annual Rates of Labour Productivity Growth and the Contributions of Capital Intensity, Labour Composition, and Multifactor Productivity, Canadian and U.S. Business Sectors (percentage)

	1981-2000		1981-1988		1988-1995		1995-2000*	
	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.
Labour Productivity Growth	1.4	1.9	1.3	1.9	1.2	1.4	1.8	2.7
Capital Deepening	0.6	0.7	0.6	0.6	0.8	0.5	0.5	1.1
Information Technology	0.4	0.6	0.3	0.5	0.4	0.4	0.5	1.0
Other Machinery and Equipment	0.1	0.0	0.2	0.0	0.1	0.0	0.2	0.1
Structures	0.1	0.1	0.1	0.2	0.3	0.1	-0.2	0.0
Labour Composition	0.5	0.3	0.5	0.3	0.6	0.4	0.3	0.3
Multifactor Productivity	0.3	0.9	0.3	0.9	-0.2	0.5	1.1	1.4

* The labour productivity estimates are those released in July 2002. Therefore, they do not include the more recent revisions implemented by both Canada and the U.S.

deepening can be attributed to increases in information technology investment. Moreover, this proportion increases over the period.

From 1981 to 1988, multifactor productivity in Canada grew at an average annual rate of 0.3% (0.9% in the U.S.). This rate, combined with the 0.6 percentage points contribution of capital deepening (0.6 percentage points in the U.S.) and the 0.5 percentage points contribution of labour composition (0.3 percentage points in the U.S.), resulted in a labour productivity growth rate of 1.3% (1.9% in the U.S.).

During the period 1980-1995, Canadian multifactor productivity declined at -0.2% per year. At the same time, the average annual contribution of capital deepening to labour productivity growth increased to 0.8 percentage points, and labour composition made a 0.6 percentage points contribution. Labour productivity, therefore, increased 1.2% (1.4% in the U.S.) per year during this period.

Information technology capital played a very important role during this period in the capital deepening process. These forms of capital contributed 0.4 percentage points per year to labour productivity growth in both Canada and the U.S. This corresponds to half of the 0.8 percentage points growth in the contribution of capital deepening in Canada (80% for the U.S.).

From 1995 to 2000, output per hour grew 1.8% per year in the business sector (2.7% in the U.S.), 0.6 percentage points faster than during the 1988-1995 period (1.3 percentage points in the U.S.). Most of the increased growth can be attributed to faster multifactor productivity growth, which surged by 1.1 percentage points (1.4 percentage points for the U.S.).

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Appendix 4.A—Tax Variables of the User Cost of Capital: Sources and Construction of the Estimates

The user cost of capital formula (4) requires the estimates of the following tax variables:

- The corporate income tax rates;
- The investment tax credit rate on corporate assets;
- The present value of capital consumption allowances;
- The property tax rate on corporate assets.

1. Corporate Income Tax Rate

1.1. Sources of the Data

We used the following variables obtained from various sources of information.

A) Taxable Income by Industry and by Province

Source A1: The data for 43 industries and 10 provinces based on the 1960 SIC-E cover the period 1961-1987 (Industrial Organization and Finance Division (IOFD)) data from CANSIM, Matrices 3332, 3334, 3336, 3338, 3340, 3342, 3344, 3346, 3348, 3350, and 3358).[10]

Source A2: The data for 71 industries and 10 provinces based on the 1980 SIC-E cover the period 1993-1996. The source of these data is The Corporate Income Tax Administrative Database. (Statistics Canada, IOFD).[11]

We made the following adjustments to the data:

1) We imputed the missing data for the 1961-1972 period (e.g. taxable income of Quebec)

2) During the period 1993-1996, taxable income was negative for some provinces and industries (Taxable Income of Service Industries Incidental to Mineral Extraction for Ontario and Quebec in 1993). We set these negative values to zeros.

[10] Table 4.A1 lists these 43 industries.
[11] Table 4. A2 lists these 71 industries.

3) No official information was available for the 1988-1992 period. We estimated the missing data (see Section B.4 step 1 in this Appendix);

4) The sources A1 and A2 are based on two different industrial classifications; therefore, a conversion to a unique industrial classification was implemented based on the 1960 SIC-E.

B) Taxable Income and Small Business Deductions by Industry (not by province)

The information on each variable was available from the following sources:

Source B1: The data for 44 industries based on the 1960 SIC-E cover the 1974-1987 period (IOFD data from CANSIM, Matrices 5326-5369).

Source B2: The data for 68 industries based on the 1980 SIC-C cover the 1988-1994 period (IOFD data from CANSIM, Matrices 4100-4167).

These sources raised the following issues:

1) The missing data for the 1961-1973 period were therefore imputed (see Section B.4 step 1 in this appendix);

2) The sources B1 and B2 are based on two different industrial classifications.

C) Combined Corporate Income Tax Rates

Source C1: The data, which cover 10 provinces for the period 1961-1988, were taken from Perry (1989), Table 16.6, p. 396.

Source C2: For the subsequent period, the data were obtained from various issues of the Canadian Tax Foundation.

The statutory corporate tax rates are available at combined federal and provincial level by firm size and sector of activity (mainly manufacturing and processing activities and nonmanufacturing and nonprocessing). These rates are available from various issues of the Canadian Tax Foundation and Perry (1989).

1.2. Construction of the Estimates

A) Overview

To estimate the Canadian corporate income tax rates for the 1961-1996 period by industry, we constructed the following variables:

a) Combined federal and provincial manufacturing and processing small business tax rates;

b) Combined federal and provincial manufacturing and processing large businesses tax rates;

c) Combined federal and provincial small businesses tax rates;

d) Combined federal and provincial large businesses tax rates;

e) The distribution of taxable income by industry across provinces;

f) The small businesses' share of taxable income.

The variables a) - f) are used as follows:

i) Construction of combined tax rates by industry: the variables a)-d) were broken-down by industry using e) as an allocation factor by industry;

ii) These combined tax rates by industry were then aggregated using the share of small and large businesses (the share is based on f).

The industrial breakdown of the tax parameter was done for the 42 industry groupings of the 1960 SIC-E. We assumed that industries from 9 to 30 constitute manufacturing and processing, while the remaining industries were considered as non-manufacturing and non-processing (see Table 4.A1).

B) The Detailed Approach

B.1) Provincial taxable income allocation

Step 1: Getting Consistent Industry Groupings Between the Sources A1and A2:

The 71 industries from source A2 are aggregated into 43 industries to get a consistent time series for taxable income by industry and province, for the 1961-1987 and 1993-1996 periods.

Step 2: Estimating the Corporate Taxable Income Share by Industry for Each Province:

Once the data on taxable income by industry and province for the periods 1961-1987 and 1993-1996 were constructed, the share of corporate taxable income by industry for each province was estimated as:

$$\alpha_{i,p,t} = \frac{Taxable\ Income_{i,p,t}}{\sum_{p=1}^{10} taxable\ Income_{i,p,t}}, \tag{A.1}$$

where

$i = 1,2,.......42$ *industries*

$p = 1,2,.......10$ *provinces*

$t = 1,2,.......36$ *years*

$\alpha_{i,p,t}$: the share of taxable income of the industry i in the province p in year t.

B.2) Taxable income share of small businesses by industry

Estimates of the taxable income share of small businesses by industry required the source B1 and B2.

Step 1: Getting Consistent Industry Groupings Between the Sources B1 and B2:

The source B2 based on the 1980 SIC-C was made consistent with the source B1, based on 43 industries of the 1960 SIC-E. This consistency was applied for both the taxable income and the small business deduction.

The following example for food industry illustrates how we transformed the 1980 SIC-C data to conform to the 1960 SIC-E industrial breakdown. The 1980 SIC-C is based on the concept of consolidation. In other words, the industry classification reflects the multiple activities in which an enterprise may be engaged:

$$\text{Taxable Income}^{1960SIC\text{-}E}_{Food,t=88} = \left(\frac{\text{Taxable Income}^{1960SIC\text{-}E}_{Food,t=87}}{\text{Taxable Income}^{1960SIC\text{-}E}_{Agriculture,t=87} + \text{Taxable Income}^{1960SIC\text{-}E}_{Fishing\&Trapping,t=87} + \text{Taxable Income}^{1960SIC\text{-}E}_{Food,t=87}} \right) \times \text{Taxable Income}^{1980SIC\text{-}C}_{Food,t=88} \quad (A.2)$$

The same method was applied for small business deduction.

Step 2: Calculation of the Share of Taxable Income for Small Businesses:

Taxable income for small business was not available from CANSIM data but the information exists through IOFD Custom Tabulation for the period 1988 onward.

We decided to proxy the taxable income for small business by the ratio of the small business deduction to the difference between General corporate tax rates and Small business tax rates (see below for tax estimation methodology). Therefore, the share of taxable income for small business by industry is measured as:

$$\Delta_{i,t} = \frac{Small\ Business\ Deduction_{i,t}}{Taxable\ Income_{i,t}\left(General\ tax\ rate_{i,t} - Small\ Business\ rate_{i,t}\right)} \quad (A.3)$$

B.3) Combined Federal and Provincial Income Tax Rates

Four kinds of combined federal and provincial corporate tax rates for each province are available from various issues of the Canadian Tax Foundation and Perry (1989).

- Combined Small Business rate
- Combined General Tax rate
- Combined Small Business manufacturing and processing rate
- Combined General Tax manufacturing and processing rate

B.4) Calculation of Corporate Income Tax Rates

Step 1: Calculation of the Weighted Sum of Combined Corporate Income Tax Rates:

The share of taxable income for small businesses was not available for the period 1961-1973. We used the average share of 20% estimated by Boadway and Kitchen (1980).

$$\begin{aligned} Small\ Business\ rate_{i,t} &= \left(\sum_{p=1}^{10} \alpha_{i,p}.Combined\ Small\ Business\ rate_p \right)_t \\ General\ tax\ rate_{i,t} &= \left(\sum_{p=1}^{10} \alpha_{i,p}.Combined\ General\ Tax\ rate_p \right)_t \end{aligned} \tag{A.4}$$

The industries listed from 9 to 30 are considered as manufacturing and processing industries, and their tax rates are calculated as follows:

$$\begin{aligned} Small\ Business\ M\ \&\ P\ rate_{i,t} &= \left(\sum_{p=1}^{10} \alpha_{i,p}.Combined\ Small\ Business\ M\ \&\ P\ rate_p \right)_t \\ General\ M\ \&\ P\ rate_{i,t} &= \left(\sum_{p=1}^{10} \alpha_{i,p}.Combined\ General\ M\ \&\ P\ rate_p \right)_t \end{aligned} \tag{A.5}$$

The missing data on taxable income by industry and by province during the period of 1988-1992 were imputed using the information available in 1987 and 1992. In particular, it is assumed that for each industry and province, the taxable income share between 1988-1992 is the average of 1987 and 1992 shares.

Step 2: Calculation of the Average Combined Federal and Provincial Corporate Tax Rates:

Finally, we calculated the average rates as follows:

- For the industries from 1 to 8 and from 31 to 43:

$$\begin{aligned} Average\ rate_{i,t} &= Small\ Business\ rate_{i,t} \times \Delta_{i,t} \\ &+ General\ tax\ rate_{i,t} \times \left(1 - \Delta_{i,t}\right) \end{aligned} \tag{A.6}$$

- For the industries from 9 to 30:

$$\begin{aligned} Average\ rate_{i,t} &= Small\ Business\ M\ \&\ P\ rate_{i,t} \\ &\times \Delta_{i,t} + Other\ M\ \&\ P\ rate_{i,t} \times \left(1 - \Delta_{i,t}\right) \end{aligned} \tag{A.7}$$

where $\Delta_{i,t}$ is defined in A.3 as the small businesses' share of taxable income.

2. Investment Tax Credit Rate

There are various rates by type of capital used in different regions in Canada.

2.1 Sources of the Data

We used the statutory investment tax credit rates from the following source of information.

Source A: The investment tax rates for the period 1975-1996, were taken from Williamson and Lahmer (1996, p. 2,664).

The following types of capital assets have been considered:

- Qualified property;
- Qualified transportation and construction equipment;
- Qualified scientific research expenditures for Canadian-controlled private corporations;
- Qualified scientific research expenditures for non Canadian-controlled private corporations.

2.2 Construction of the Estimates

We computed the investment tax credit rate for the period 1975-1988, assuming that the investment tax credit for equipment and structures were instituted in Canada in 1975 and repealed in 1989. We reported the general rate applied in other locations in Canada.

Jung (1989) and McKenzie *et al.* (1998) suggested that the statutory investment tax credit rates could not be used because the investment tax credit is not available for all types of depreciable assets. McKenzie *et al.* (1998) calculated average effective investment tax credit rates instead of statutory rates by industry and capital cost allowance class. In addition to industry and capital cost allowance classes, Jung (1989) introduced the firm size as a third characteristic.

3. Present Value of Capital Cost Allowances

3.1 Formulae and Sources of the Data

Source A: The formulae used to calculate the present value of capital cost allowances by asset class, for the 1961-1996 period, were taken from Jung (1989), Boadway, Bruce and Mintz (1983), Boadway, Bruce and Mintz (1987), Boadway and Kitchen (1999), and Dougherty (1991). These formulae require information on the depreciable rate δ under various depreciation methods (declining-balance method and straight-line method), the corporate income tax rate τ and the interest rate i.

The formulae are :

a) For the declining-balance method:

The present value of capital cost allowances is:

- In case of full amount of capital cost in the first year:

$$z = \frac{\delta}{\left(i \times (1-\tau) + \delta\right)} \tag{A.8}$$

where:

δ = The tax allowable depreciation rate;

i = The nominal interest rate (The Government of Canada Three Month Treasury Bills);

τ = The corporate income tax rate.

- In case of half amount of the capital cost allowance for the first year:

$$z = \frac{\frac{1}{2} \times \delta}{\left(i \times (1-\tau) + \delta\right)} + \frac{1 - \frac{1}{2} \times \delta}{\left(1 + i \times (1-\tau)\right)} \times \left(\frac{\delta}{\left(i \times (1-\tau) + \delta\right)}\right) \tag{A.9}$$

b) For the straight-line depreciation method:

The present value of capital cost allowances is:

$$z = \frac{\delta}{i \times (1-\tau)} \times \left(1 - \frac{1}{\left(1 + i \times (1-\tau)\right)^{T}}\right) \tag{A.10}$$

where:

T = the lifetime of the asset

c) For the 3 years straight-line depreciation method:

The present value of capital cost allowances is:

$$z = \frac{\frac{1}{4}}{\left(1 + i \times (1-\tau)\right)} + \frac{\frac{1}{2}}{\left(1 + i \times (1-\tau)\right)^{2}} + \frac{\frac{1}{4}}{\left(1 + i \times (1-\tau)\right)^{3}} \tag{A.11}$$

3.2 Construction of the Estimates

We considered two categories of assets: structures and machinery and equipment. We, then, estimated the present value of capital cost allowances using the same method of Boadway, Bruce and Mintz (1987). This method is outlined below:

1) For building structures:

The present value of capital cost allowances was calculated as follows:

- For the 1961-1962 period, the declining balance method in case of a full amount of the capital cost allowances for the first year (equation A.8) was used with δ =0.05.

- For the 1963-1966 period, the straight-line method (equation A.10) was used with δ =0.2 and T =5.

- For the 1967-1981 period, the declining balance method in case of a full amount of the capital cost allowances for the first year (equation A.8) was used with δ =0.05.

- For the 1982-1996 period, the declining balance method in case of a half amount of the capital cost allowances for the first year (equation A.9) was used with δ =0.05.

2) For machinery and equipment:

The present value of capital cost allowances is:

2-1 For non-manufacturing and non-processing firms:

- For the 1961-1962 period, the declining balance method in case of a full amount of the capital cost allowances for the first year (equation A.8) was used with δ =0.2.

- For the 1963-1966 period, the straight-line method (equation A.10) was used with δ =0.5 and T =2.

- For the 1967-1981 period, the declining balance method in case of a full amount of the capital cost allowances for the first year (equation A.8) was used with δ =0.2.

- For the 1982-1996 period, the declining balance method in case of a half amount of the capital cost allowances for the first year (equation A.9) was used with δ =0.2.

2-2 For manufacturing and processing firms:

- For the 1961-1962 period, the declining balance method in case of a full amount of the capital cost allowances for the first year (equation A.8) was used with δ =0.2.

- For the 1963-1966 period, the straight-line method (equation A.10) was used with δ =0.5 and T =2.

- For the 1967-1971 period, the declining balance method in case of a full amount of the capital cost allowances for the first year (equation A.8) was used with δ =0.2.

- For the 1972-1981 period, the straight-line method (equation A.10) was used with δ =0.5 and T =2.

- For the 1982-1996 period, the straight-line method (equation A.11) was used.

Following Boadway et al. (1987), we assumed that assets used in manufacturing and processing firms between 1970 and 1972 were allowed to be written off at the regular rate but using as a depreciation base 115 per cent of the original cost.

Boadway et al. (1987) calculated the average capital cost allowance rate by taking a weighted average capital cost allowance of rates of the most important classes. For buildings, they assumed that most investment occurred in class 3. For machinery, the most important classes were 2, 8, 10, and 29. They then calculated the present value of capital cost allowances for manufacturing and non-manufacturing and finally aggregated.[12]

4. Property Tax Rate on Corporate Assets

4.1 Sources of the Data

Source A1: The data, which cover indirect taxes on production of 167 industries for the period 1961-1995, were taken from Input Output Tables (System of National Accounts, Input-Output Division).

Source A2: The methodology on the construction of capital stock net of geometric depreciation by industry for the period 1961-1996 were described in section 4.5.2 of this chapter.

Source A2: The construction of the inventories and land series by industry for the period 1961-1998 were discussed in Tanguay (2001).

[12] The class 3 includes the following assets: building and other structure, breakwater, dock, trestle, windmill, wharf, telephone, telegraph, or data communication equipment.

The class 2 includes the following assets: electrical generating equipment, pipeline, other than gas or oil well equipment, the generating or distributing equipment and plant of a producer or distributor of electrical energy, manufacturing and distributing equipment and plant, the distributing equipment and plant.

The class 8 includes the following assets: structure that is manufacturing or processing machinery or equipment, tangible property attached to a building and acquired solely, electrical generating equipment, portable electrical generating equipment, a rapid transit car.

The class 10 includes the following assets: automotive equipment, a portable tool, harness or stable equipment, a sleigh or wagon, a trailer, general-purpose electronic data processing equipment and systems software, a contractor's movable equipment.

The class 29 includes the following assets: property manufactured by the taxpayer, An oil or water storage tank, a powered industrial lift truck, electrical generating equipment.

4.2 Construction of the Estimates

The indirect taxes on production from Input Output Tables for the 1961-1995 period for 167 industries were aggregated to 123 industries, which is the level at which Input-Output Data and Capital Stock Data can be combined to produce productivity estimates.

The property tax rate was then calculated as follows:

$$v_{i,t} = \frac{\text{Indirect Taxes on Production}_{i,t}}{\left(\text{Capital Stock of Building}_{i,t} + \text{Capital Stock of Engineering} + \text{Land}_{i,t}\right)}, \qquad \text{(A.12)}$$

where,

$v_{i,t}$ = The property tax rate for the industry i on year t;

Capital $\text{Stock}_{i,t}$ = The nominal value of stock capital of building and engineering;

$\text{Land}_{i,t}$ = The nominal value of land.

Table 4.A1: Industrial Structure, 1960 SIC-E

Non-manufacturing and Non-processing

- Total Agricultural, Forestry and Fishing
- Agriculture
- Forestry
- Fishing and Trapping
- Total Mining
- Metal Mining
- Mineral Fuels
- Other mining
- Total Transport, Communications and Utilities
- Transportation
- Storage
- Communication
- Public Utilities
- Wholesale Trade
- Retail Trade
- Finance
- Total Services
- Services to Business Management
- Goverment Personal and Miscellanous Services
- Construction

Manufacturing and Processing

- Total Manufacturing
- Food
- Beverages
- Tobacco Products
- Rubber Products
- Leather Products
- Textile Mills
- Knitting Mills
- Clothing Industries
- Wood Industries
- Furniture Industries
- Paper and Allied Industries
- Printing Publishing and Allied Industries
- Primary Metals
- Metal Fabricating
- Machinery
- Transport Equipment
- Electrical Products
- Non Metallic Mineral Products
- Petroleum and Coal Products
- Chemicals and Chemical Products
- Miscellaneous Manufacturing
- All Industries

Table 4.A2: Industrial Structure, 1980 SIC-E

Agricultural Industries
Service Industries Incidental to Agriculture
Fishing and Trapping Industries
Logging Industry
Forestry Services Industry
Mining Industries
Crude Petroleum and Natural Gas Industries
Quarry and Sand Pit Industries
Service Industries Incidental to Mineral Extraction
Food Industries
Beverage Industries
Tobacco Products Industries
Rubber Products Industries
Plastic Products Industries
Leather and Allied Products Industries
Primary Textile Industries
Textile Products Industries
Clothing Industries
Wood Industries
Furniture and Fixture Industries
Paper and Allied Products Industries
Printing, Publishing and Allied Industries
Primary Metal Industries
Fabricated Metal Products Industries (except Machinery and Transportation Equipment)
Machinery Industries (except Electrical Machinery)
Transportation Equipment Industries
Electrical and Electronic Products Industries
Non-Metallic Mineral Products Industries
Refined Petroleum and Coal Products Industries
Chemical and Chemical Products Industries
Other Manufacturing Industries
Building, Developing and General Contracting Industries
Industrial and Heavy (Engineering) Construction Industries
Trade Contracting Industries
Service Industries Incidental to Construction
Transportation Industries
Pipeline Transport Industries
Storage and Warehousing Industries
Communication Industries
Other Utility Industries
Farm Products Industries, Wholesale
Petroleum Products Industries, Wholesale
Food, Beverage, Drug and Tobacco Industries, Wholesale
Apparel and Dry Goods Industries, Wholesale
Household Goods Industries, Wholesale
Motor Vehicle, Parts and Accessories Industries, Wholesale
Metals, Hardware, Plumbing, Heating and Building Materials Industries, Wholesale
Machinery, Equipment and Supplies Industries, Wholesale
Other Products Industries, Wholesale
Food, Beverage and Drug Industries, Retail
Shoe, Apparel, Fabric and Yarn Industries, Retail
Household Furniture, Appliances and Furnishings Industries, Retail
Automotive Vehicles, Parts and Accessories Industries, Sales and Service
General Retail Merchandising Industries
Other Retail Store Industries
Non-Store Retail Industries
Deposit Accepting Intermediary Industries
Consumer and Business Financing Intermediary Industries
Investment Intermediary Industries
Insurance Industries
Other Financial Intermediary Industries
Real Estate Operator Industries (except Developers)
Insurance and Real Estate Agent Industries

Table 4.A2: Industrial Structure, 1980 SIC-E – *concluded*
Business Service Industries
Educational Service Industries
Health and Social Service Industries
Accommodation Service Industries
Food and Beverage Service Industries
Amusement and Recreational Service Industries
Personal and Household Service Industries
Membership Organization Industries
Other Service Industries

Appendix 4.B—Aggregation of Capital Services

This appendix provides a formal treatment of the construction of the aggregate capital stock and capital services over 23 categories of fixed reproducible assets in addition of land and inventories. For illustration purposes, we aggregate in two stages: first, we grouped these 23 assets into three asset classes—information technology, other machinery and equipment, structures including land and inventories. These groupings may be useful for analytical needs such as those related to the new economy (see Chapter 1 for example). In the second stage, the three asset classes are aggregated into a broader index of "total capital services." It is this broad index of total capital services that is appropriate for the aggregate production function.

The various methods of aggregation have been much discussed elsewhere and we shall not elaborate on them here (see Diewert 1980a). Suffice it to say, we use the Fisher index due to its exact aggregation properties.

Asset Class Indexes

We begin by defining four variables that are relevant for productivity analysis for each asset class j, where j represents the following three asset classes: information technology, other machinery and equipment and structures.[13] $\tilde{K}_t^j$ is an index of capital services; $\hat{K}_t^j$ is an index of capital stock; K_t^j is a simple sum of capital stock; and q_t^j is an index of quality, all for asset class j at time t.

The quantity index of capital services for asset class j is defined as the Fisher aggregate of the different assets that comprise the asset class:

$$\tilde{K}^j_{t\ t-1} = \sqrt{\sum_{a\in A} v_{at-1}\left(\frac{K_{at}}{K_{at-1}}\right)\cdot\sum_{a\in A} v_{at}\left(\frac{K_{at}}{K_{at-1}}\right)} \tag{B.1}$$

where A is the set of all assets that belong to asset class j and weights v_{at} and v_{at-1} are rental cost shares defined as:

$$v_{at} = \frac{c_{at}K_{at-1}}{\sum_{a\in A} c_{at}K_{at-1}} \equiv \frac{V_{at}}{V_t^j} \quad \text{and} \quad v_{at-1} = \frac{c_{at-1}K_{at-1}}{\sum_{a\in A} c_{at-1}K_{at-1}} \equiv \frac{V_{at-1}}{V_{t-1}^j}$$

[13] These asset classes comprise the non-residential assets listed in Table 4.4, four residential assets, land and inventories.

where V_t^j and V_{t-1}^j are the nominal values of capital services in class j in year t and $t-1$.

The rental cost index of capital services for asset class j in year t is given by:

$$c_t^j = \frac{V_t^j}{\tilde{K}_t^j}$$

Similarly, the quantity index of capital stock for asset class j is given by:

$$\hat{K}^j_{t/t-1} = \sqrt{\sum_{a \in A} w_{at-1}\left(\frac{K_{at}}{K_{at-1}}\right) \cdot \sum_{a \in A} w_{at}\left(\frac{K_{at}}{K_{at-1}}\right)} \tag{B.2}$$

where weights are now value shares of the capital stock defined as:

$$w_{at} = \frac{q_{at}K_{at-1}}{\sum_{a \in A} q_{at}K_{at-1}} \equiv \frac{W_{at}}{W_t^j} \text{ and } w_{at-1} = \frac{q_{at-1}K_{at-1}}{\sum_{a \in A} q_{at-1}K_{at-1}} \equiv \frac{W_{at-1}}{W_{t-1}^j}$$

where q_{at} is the price of the asset, W_t^j and W_{t-1}^j are the nominal values of capital stock in class j in year t and $t-1$.

The price index of capital stock for class j is defined as:

$$q_t^j = \frac{W_t^j}{\hat{K}_t^j}$$

We also define an alternative measure of the capital stock for class j assets as the simple sum of the constant dollar stocks:

$$\bar{K}_t^j = \sum_{a \in A} K_{at} .$$

We define the index of capital quality for class j as:

$$\tilde{K}_t^j = \Delta_t^j \cdot \bar{K}_t^j \tag{B.3}$$

which can be rewritten as

$$\ell n\left(\frac{\Delta_t^j}{\Delta_{t-1}^j}\right) = \ell n\left(\frac{\tilde{K}_t^j}{\tilde{K}_{t-1}^j}\right) - \ell n\left(\frac{\bar{K}_t^j}{\bar{K}_{t-1}^j}\right) \tag{B.4}$$

Growth in the index of capital quality equals the difference in the growth rate of capital services and a simple sum of the capital stock. Note that capital quality for class j in (B.3) is indexed by time and varies in (B.4), while asset-specific capital quality is a constant. This reflects the specific definition of capital quality in this context. As relative rental prices changes, firms substitute between assets within each asset class and this capital-capital substitution is what we refer to as growth in capital quality.

Aggregate Indexes

We now define similar variables at higher levels of aggregation. Fixed reproducible capital is an aggregate over the three classes of assets listed above, while total capital is an aggregate over the same three classes. Both calculations are based on the methodology that follows and only differ on which components are included. The index of aggregate capital services is defined as the Fisher aggregate of the components as:

$$\tilde{K}_{t/t-1} = \sqrt{\sum_j v_{t-1}^j \left(\frac{K_{jt}}{K_{jt-1}}\right) \cdot \sum_j v_t^j \left(\frac{K_{jt}}{K_{jt-1}}\right)} \tag{B.5}$$

where the weights are again value shares of capital income

$$v_t^j = \frac{c_t^j K_{t-1}^j}{\sum_j c_t^j K_{t-1}^j} \equiv \frac{V_t^j}{V_t} \quad \text{and} \quad v_{t-1}^j = \frac{c_{t-1}^j K_{t-1}^j}{\sum_j c_{t-1}^j K_{t-1}^j} \equiv \frac{V_{t-1}^j}{V_{t-1}}$$

where V_t and V_{t-1} are the nominal values of capital income for all asset classes.

The rental cost index of capital services for aggregate capital is:

$$c_t = \frac{V_t}{\tilde{K}_t}$$

Similarly, the aggregate quantity index of capital stock is given by:

$$\hat{K}_{t/t-1} = \sqrt{\sum_j w_{t-1}^j \left(\frac{K_t^j}{K_{t-1}^j}\right) \cdot \sum_j w_t^j \left(\frac{K_t^j}{K_{t-1}^j}\right)}$$

where weights are again value shares of the aggregate capital stock:

$$w_t^j = \frac{q_t^j K_{t-1}^j}{\sum_j q_t^j K_{t-1}^j} \equiv \frac{W_t^j}{W_t} \quad \text{and} \quad w_{t-1}^j = \frac{q_{t-1}^j K_{t-1}^j}{\sum_j q_{t-1}^j K_{t-1}^j} \equiv \frac{W_{t-1}^j}{W_{t-1}}$$

The price index of the aggregate capital stock index is

$$q_t = \frac{W_t}{\hat{K}_t}$$

Finally, we have the simple sum of the aggregate capital stock:

$$\bar{K}_t = \sum_j K_t^j \, .$$

We can now define the quality index for aggregate capital. Using the same definition as in equation (B.3) above, we have:

$$\tilde{K}_t = \Delta_t \cdot \bar{K}_t \, .$$

which implies that the growth in the quality of aggregate capital is:

$$\ell n\left(\frac{\Delta_t}{\Delta_{t-1}}\right) = \ell n\left(\frac{\tilde{K}_t}{\tilde{K}_{t-1}}\right) - \ell n\left(\frac{\bar{K}_t}{\bar{K}_{t-1}}\right) \tag{B.6}$$

It is useful to rewrite (B.6) to provide more economic intuition as

$$\ell n\left(\frac{\Delta_t}{\Delta_{t-1}}\right) = \left[\ell n\left(\frac{\tilde{K}_t}{\tilde{K}_{t-1}}\right) - \ell n\left(\frac{\hat{K}_t}{\hat{K}_{t-1}}\right)\right] + \left[\ell n\left(\frac{\hat{K}_t}{\hat{K}_{t-1}}\right) - \ell n\left(\frac{\bar{K}_t}{\bar{K}_{t-1}}\right)\right] \tag{B.7}$$

The first set of brackets measures the difference in the growth rates of capital services and the capital stock index. This reflects substitution between assets in response to rental price changes. The term in the second set of brackets measures the difference in growth rates between the capital stock index and the simple sum of capital stocks. This is to highlight the difference between our measure and the simple sum that has been used in other studies. As should be clear from these equations, simply summing constant dollar quantities will lead to a biased index since it does not account for changes in relative prices.

As a final step, it is useful to decompose growth in the aggregate index of capital services into several components that reflect changes both between and within asset classes. Applying capital income shares to equation (B.4) and summing over asset classes we get:

$$\sum_j \bar{v}_t^j \ell n\left(\frac{\tilde{K}_t^j}{\tilde{K}_{t-1}^j}\right) = \sum_j \bar{v}_t^j \ell n\left(\frac{\Delta_t^j}{\Delta_{t-1}^j}\right) + \sum_j \bar{v}_t^j \ell n\left(\frac{\bar{K}_t^j}{\bar{K}_{t-1}^j}\right) \tag{B.8}$$

From (B.5) and (B.6) we have:

$$\sum_j \bar{v}_t^j \ell n\left(\frac{\tilde{K}_t^j}{\tilde{K}_{t-1}^j}\right) = \ell n\left(\frac{\Delta_t}{\Delta_{t-1}}\right) + \ell n\left(\frac{\bar{K}_t}{\bar{K}_{t-1}}\right) \tag{B.9}$$

Combining the above two equations, the growth in aggregate quality may be expressed as:

$$\ell n\left(\frac{\Delta_t}{\Delta_{t-1}}\right) = \sum_j \bar{v}_t^j \ell n\left(\frac{\Delta_t^j}{\Delta_{t-1}^j}\right) + \sum_j \bar{v}_t^j \ell n\left(\frac{\bar{K}_t^j}{\bar{K}_{t-1}^j}\right) \quad \ell n\left(\frac{\bar{K}_t}{\bar{K}_{t-1}}\right)$$

Substituting this into equation (B.6), and adding and subtracting $\sum_j \bar{w}_t^j \ell n\left(\frac{\bar{K}_t^j}{\bar{K}_{t-1}^j}\right)$ yields the following decomposition of the growth in aggregate capital services:

$$\begin{aligned} \ell n\left(\frac{\tilde{K}_t}{\tilde{K}_{t-1}}\right) &= \left[\ell n\left(\frac{\Delta_t}{\Delta_{t-1}}\right)\right] + \left[\ell n\left(\frac{\bar{K}_t}{\bar{K}_{t-1}}\right)\right] \\ &= \sum_j \bar{v}_t^j \ell n\left(\frac{\Delta_t^j}{\Delta_{t-1}^j}\right) + \sum_j (\bar{v}_t^j - \bar{w}_t^j) \ell n\left(\frac{\bar{K}_t^j}{\bar{K}_{t-1}^j}\right) + \sum_j \bar{w}_t^j \ell n\left(\frac{\bar{K}_t^j}{\bar{K}_{t-1}^j}\right) \end{aligned} \qquad (B.10)$$

This expression, which represents aggregate quality change, is a bit complicated, but each piece has a specific economic interpretation. We refer to the first parentheses as the "within quality effect," which measures substitution and capital quality growth within distinct asset classes. The second parentheses represent the "between quality effect," which measures substitution between distinct asset classes. The third parentheses represents an "index quality effect," which captures the growth rate of the capital index. The last term is the "capital accumulation effect," which measures raw capital accumulation.

5 Unit Labour Costs and the Competitiveness of Canadian Businesses

Mustapha Kaci and Jean-Pierre Maynard

5.1 Introduction

Unit labour cost is the wage expense that a business incurs per unit of output. It increases when the wage rate rises more rapidly than labour productivity. Because it reflects both productivity gains and wage inflation, the growth of unit labour cost (ULC) is related to businesses' long-term performance. Given the importance of international competitiveness, controlling wage costs has always been a major objective for Canadian businesses.

In this study, we begin by reviewing the characteristics of the ULC in the business sector, and we answer the following questions: What exactly is this indicator? How is it measured? We then explain the different mechanisms by which the ULC serves as a leading indicator of the evolution of costs in businesses. For this purpose, we compare the ULC indicator to a more complete measure of variable costs, which also include the costs of raw materials, energy and subcontracted services. The evolution of the partial measure, the ULC, is compared to the evolution of variable costs in general for the business sector and for manufacturing in Canada during the period 1961-1997. This leads us to examine trends in the evolution of ULCs in the Canadian business sector during the past four decades. Finally, the ULC is used to analyse the competitiveness of the Canadian manufacturing sector in relation to its U.S. counterpart for the past decade. For manufacturing industry groups at the two-digit level, the relationship between export growth and the relative unit cost is also examined.

5.2 Definition and Measurement of the Unit Labour Cost

To better grasp the concept of the unit labour cost, it is useful to situate it in the context of the different costs involved in production. By briefly enumerating the different types of costs that a business faces, we can better situate the concept of ULC. Appendix 5.A provides an overview of the concepts relating to production costs.

The unit (or average) labour cost is the compensation of labour in nominal terms per unit of output:

$$\text{Unit labour cost} = \frac{\text{Total labour compensation}}{\text{Real output}} \quad (1)$$

Thus, for a business that manufactures motorcycles, the unit labour cost for a given period can be calculated if we know the payroll of its employees and the number of units produced. For example, if this business produces ten motorcycles per hour and

has 500 employees earning an average of $20 per hour the ULC (cost of labour per unit produced) will be $1,000 (500 X $20/10).

At the aggregate level, output can only be measured in terms of value, that is, in dollars, and not in terms of physical volume (quantity produced), since it is not possible to put telephone services, vehicles and chairs on the same footing without using the value of each. Because of the vast number of goods and services produced and the difficulty of finding a common unit of measurement for all of them, output is measured in monetary terms.

To make comparisons of real output from one year to another, it is also necessary to eliminate the effect of a general movement of prices. Thus, the change in quantities produced is estimated by eliminating general price inflation, that is, by calculating output in period *t* at the price of another period, usually a previous year. This measure gives an indication of the real increase in output, an increase not associated with price changes.

The unit labour cost is a ratio: its value increases with the increases in the numerator—labour compensation—or decreases with increases in the denominator—real output. Thus far, we have dealt with wage costs only at the level of the individual business. Costs considered for businesses in general are nothing other than an aggregation of the individual costs of each business. Thus, the ULC for the business sector as a whole is defined as follows:

$$\text{ULC} = \frac{\text{Total compensation for all jobs}}{\text{Real value-added}} \qquad (2)$$

For the business sector as a whole, the concept of unit cost usually refers to the ratio between total compensation for all jobs and real value-added.

When calculating the unit cost for a business, real value-added is used as a measure of output. It reflects what is added by the primary factors: labour and capital. The value-added of a business consists of its gross output (mainly the amount of its sales) minus its purchases of goods and services from other businesses in order to produce that output. The aggregation of the value-added of all businesses provides a figure representing the total output of the business sector as a whole. The value-added of the business sector is also known as gross domestic product (GDP).

Total compensation for all jobs represents the total amount paid by businesses to their employees. It includes all payments in cash or in kind paid in Canada by businesses to workers in compensation for the services that they have rendered. This includes wages, salaries and supplementary labour income of paid workers, as well as an implicit labour income for self-employed workers.

5.3 The ULC as a Concept Related to Labour Productivity

The ULC of the business sector is an indicator that summarizes the evolution of labour productivity and wage compensation. The link between productivity—a measure of the improvement of the efficiency of the production process—and the unit labour cost may be shown by dividing the numerator and the denominator in the usual formula by the number of hours worked for all jobs (h):

$$ULC = \frac{\frac{\text{Total compensation for all jobs}}{h}}{\frac{\sum \text{real value-added}}{h}} = \frac{\text{Hourly compensation}}{\text{Labour productivity}} = \frac{HC}{LP} \quad (3)$$

Thus, the average unit cost of labour is equivalent to the ratio between hourly compensation (HC) and labour productivity (LP). It should be noted that value-added in real terms is calculated using a double deflation approach, by means of which real intermediate inputs are subtracted from real gross output.

Economic studies in the business sector are less concerned with the level of unit labour costs than with how these costs evolve between two periods. The goal is to evaluate the degree of control over labour costs by analysing their annual growth rates. We can obtain an approximate[1] picture of the change in ULCs using the following formula:

$$\Delta ULC = \Delta HC - \Delta LP \quad (4)$$

In other words,

% change in ULC = % change in hourly compensation - % change in labour productivity.

On the basis of this formulation, it is apparent that if hourly compensation increases faster than the productivity level, ULC will increase (Case 1). Conversely, if the labour productivity level increases faster than hourly compensation, ULC will decrease (Case 2). Furthermore, if hourly compensation increases at a fast pace and the increase in labour productivity declines at the same time, ULC will undergo two upward impulses (Case 3). Lastly, ULC will remain invariable if both its components evolve at the same pace (Case 4). These four cases are illustrated in Table 5.1 below:

Table 5.1 Behaviour of Unit Labour Costs in Response to Changes in Labour Productivity (LP) and Hourly Compensation (HC)

Case	Δ HC	Δ LP	Δ ULC
1	3%	2%	1%
2	4%	6%	-2%
3	4%	-2%	6%
4	3%	3%	0%

In summary, the evolution of the ULC is a residual between the evolution of hourly compensation and that of labour productivity.

5.4 Evolution of ULC in the Past Twenty Years

5.4.1 At the Aggregate Level

Since 1979, the Canadian business sector has experienced sizable variations in the ULC and its main components: hourly compensation and labour productivity. The following figure shows how it evolved between 1979 and 2000.

[1] Arithmetic growth rates are not completely additive. An exact relationship can be obtained using logarithmic changes.

Figure 5.1 Change in Unit Labour Costs, Hourly Compensation and Productivity in the Business Sector: 1979-2000

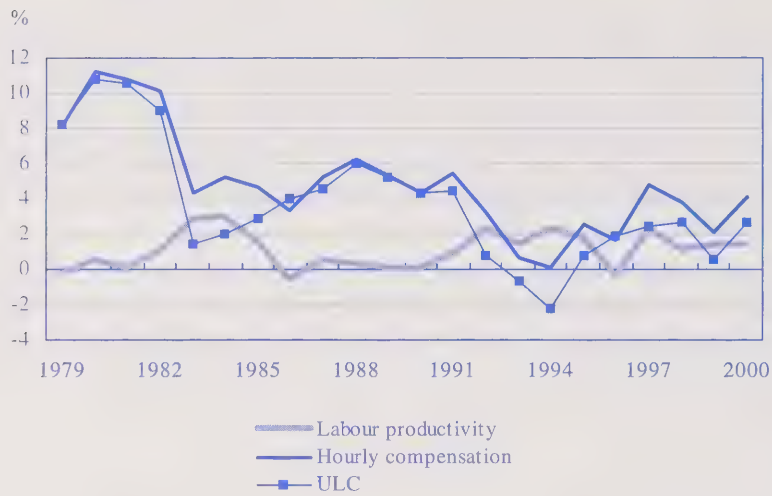


Figure 5.2 Unit Labour Costs by Sector, Average Annual Growth Rates, 1961-2000

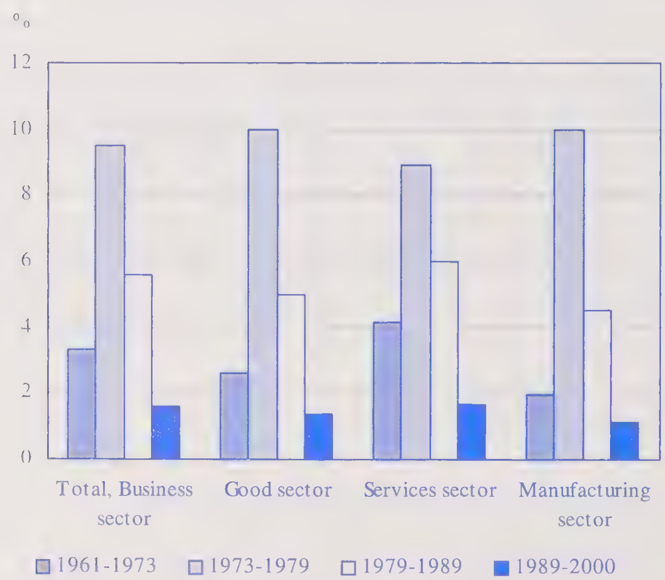


Table 5.2 Unit Labour Costs, Hourly Compensation and Labour Productivity by Major Sector, 1961-2000					
	1961-2000	1961-1973	1973-1979	1979-1989	1989-2000
			% change		
Business Sector					
Labour Productivity	2.0	3.7	1.5	1.0	1.4
Hourly Compensation	6.4	7.2	11.1	6.6	3.3
Unit Labour Costs	4.3	3.3	9.5	5.6	1.6
Goods Sector					
Labour Productivity	2.6	4.7	2.07	1.5	1.8
Hourly Compensation	6.7	7.5	12.2	6.6	3.2
Unit Labour Costs	4.0	2.6	10.0	5.0	1.4
Service Sector					
Labour Productivity	1.5	2.6	1.2	0.7	1.3
Hourly Compensation	6.2	6.9	10.3	6.7	2.9
Unit Labour Costs	4.6	4.2	8.9	6.0	1.6
Manufacturing Industries					
Labour Productivity	2.7	4.2	2.1	2.2	2.0
Hourly Compensation	6.4	6.2	12.3	6.8	3.2
Unit Labour Costs	3.6	2.6	10.0	4.5	1.1

As may be seen from Figure 5.1, between 1979 and 1982, businesses saw their ULC grow at double-digit annual rates. Subsequently, the unit labour cost grew less rapidly. It grew at an average rate of 3.6% between 1983 and 1992. Following the 1990-1991 recession, the ULC rose moderately starting in 1992, at an average rate of 1.0% per year.

In the business sector as a whole, the average growth of unit costs was limited to 1.6% during the period 1989-2000, compared with 5.6% between 1979 and 1989 (Table 5.2 and Figure 5.2). The average increase in hourly compensation slowed to 3.3% during the past decade as compared with 6.6% during the 1980s, and this, combined with the slight increase in labour productivity (1.4% per year), is largely responsible for the improved performance of Canadian businesses with respect to labour costs during the period 1989-2000.

During the past decade, the ULC increased at roughly the same rate in the two major components of the business sector: the goods sector experienced an annual rate of increase of 1.4% and the services sector, 1.6%.

Between 1989 and 2000, labour productivity grew more rapidly in the goods sector, at 1.8% (compared with 1.3% in the services sector), while the increase in hourly compensation in the goods sector increased by 3.2%, compared with 2.9% in the services sector. Thus, during this period, the relatively more modest increase in unit labour costs in the goods sector was largely due to the superior performance of labour productivity in that sector.

In manufacturing, the average annual increase in ULCs dropped, going from 4.5% per year during the period 1979-1989 to 1.1% between 1989 and 2000. This marked decline is mainly attributable to slower wage growth in manufacturing, namely 3.2% compared with 6.8% during the 1979-1989 cycle. During this time, labour productivity grew at almost the same rate during the two periods, namely 2.2% and 2.0% respectively.

The evolution of ULCs is a crucial factor in businesses' long-term performance, since it reflects both productivity gains and wage inflation. During the past four decades, the ULC grew at an average of 4.3% per year. If we divide the period from 1961 to 2000 into four sub-periods, namely 1961 to 1973, 1973 to 1979, 1979 to 1989 and 1989 to 2000, we observe that the average annual growth rate of the ULC in the business sector was much lower during the last sub-period (1.6% compared with 3.3%, 9.5% and 5.6% for the previous sub-periods). The main factor in the slower growth rate of ULC was the more modest rate of increase in hourly compensation, which declined from 6.6% in the 1980s to 2.5% between 1992 and 2000.

Since the last recession in 1991-1992, several factors have combined to create conditions more favourable to slower price and cost inflation. These include reduced pressure from demand,[2] corporate restructuring, which has resulted in major changes in the composition of the workforce; and much more modest wage increases granted when collective agreements were renewed.

5.4.2 Among Industries, Major Disparities Exist in Labour Costs

Table 5.3 shows the average annual growth rates of productivity, hourly compensation and the ULC by industry group for the past two decades: 1979-1989 and 1989-2000. Depending on the sub-period, the growth rates of unit labour costs varied considerably from one industry to another. In particular, the cost performance of industry groups during the 1990s ranged between -1.6% in agriculture and 5.0% in health care services and social services.

During the same period, agriculture registered the largest labour productivity gain (5.2%), while the largest drop was in health care services and social services (-2.9%). Disparities with respect to hourly compensation were relatively minor, with the largest observed in finance, insurance and real estate (4.5%) and the smallest in retail trade (1.7%). During the past decade, then, unit labour cost disparities among industries were mainly attributable to differences in productivity, since the increase in hourly compensation had less inter-industry variability.

5.5 The Link Between the ULC and a Broader Indicator: The Variable Cost Per Unit of Output

The cost of labour is one of the main business expenses and this is why the evolution of labour costs is often studied. However, if only labour is considered when analysing the evolution of businesses' production costs, this can give an inaccurate picture of upward pressures on costs. Those pressures also come from changes in other variable costs.

While labour costs are a major component of a business's variable production costs, they are not the only ones. Other expenses that enter into a business's variable costs include raw materials, energy and subcontracted services.

Table 5.4 gives an idea of the costs of each input as a proportion of the real gross output of the business sector and the manufacturing sector in 1997.

[2] Excess demand is reflected in movements in the price level that put pressure on ULCs.

Table 5.3 Average Annual Growth Rates of Labour Productivity, Hourly Compensation and Unit Labour Cost by Industry Group - 1979-2000

Industry	Labour Productivity		Hourly Compensation		Unit Labour Cost	
	1979-1989	1989-2000	1979-1989	1989-2000	1979-1989	1989-2000
			%			
Agriculture and Related Services	2.8	5.2	6.1	3.5	3.1	-1.6
Fishing and Trapping	-1.2	-0.9	5.1	2.6	6.4	3.5
Logging and Forestry	3.8	-0.2	6.5	3.8	2.5	4.0
Mining, Quarrying and Oil Wells	0.2	1.6	7.0	3.1	6.7	1.5
Manufacturing Industries	2.2	2.0	6.8	3.2	4.5	1.1
Construction	0.3	-0.3	6.0	2.2	5.6	2.6
Transportation and Storage	0.8	1.6	4.9	2.5	4.0	0.9
Communication and Other Utilities	1.6	2.3	5.6	2.0	4.0	-0.4
Wholesale Trade	4.6	1.9	8.5	2.0	3.7	0.1
Retail Trade	0.7	1.8	6.5	1.7	5.8	-0.1
Finance, Insurance and Real Estate	-1.1	2.7	7.2	4.5	8.5	1.7
Business Services	0.5	0.0	7.2	3.9	6.7	3.9
Private Educational Services	-3.3	-0.7	1.4	4.1	4.8	4.8
Private Health Care and Social Services	-2.6	-2.9	5.2	2.0	8.0	5.0
Accommodation and Food Services	-1.4	0.2	6.2	2.3	7.8	2.2
Other Service Industries	1.3	-0.4	6.5	2.9	5.2	3.3

Table 5.4 Costs of Each Input as a Proportion of Output, 1997

	Business Sector	Manufacturing Sector
	(percentage)	
Capital	18.2	14.0
Labour	29.9	18.4
Energy	2.7	2.5
Raw Materials	27.7	51.6
Services Purchased	21.5	13.5

Table 5.4 shows that wages and raw materials are the main variable costs in the business and manufacturing sectors. All things being equal, increases in wages and the prices of raw materials should therefore have a sizable impact on variable costs of production in these sectors.

Capital is not included in variable costs, since businesses cannot modify their production equipment in the short run by purchasing and installing new machinery. Capital is therefore considered a fixed cost in the short run. On the other hand, labour constitutes a variable cost, since a business can hire or lay off workers if the demand for its products changes suddenly.

A more complete measure of unit (or average) variable costs should take account of all inputs that may vary in the short run, including labour costs. It is therefore useful to define a broader measure of variable costs, which in this study will be called the unit variable cost (UVC), and to examine its relationship with the ULC.

The unit variable cost would thus be an indicator serving to measure all variable costs of inputs used in the short-term production process. This is a broader measure that could explain how price movements can differ from one industry to another, even if wage increases in those industries are similar.

Figure 5.3 Unit Labour Costs and Unit Variable Costs in Manufacturing Sector, 1961-1997

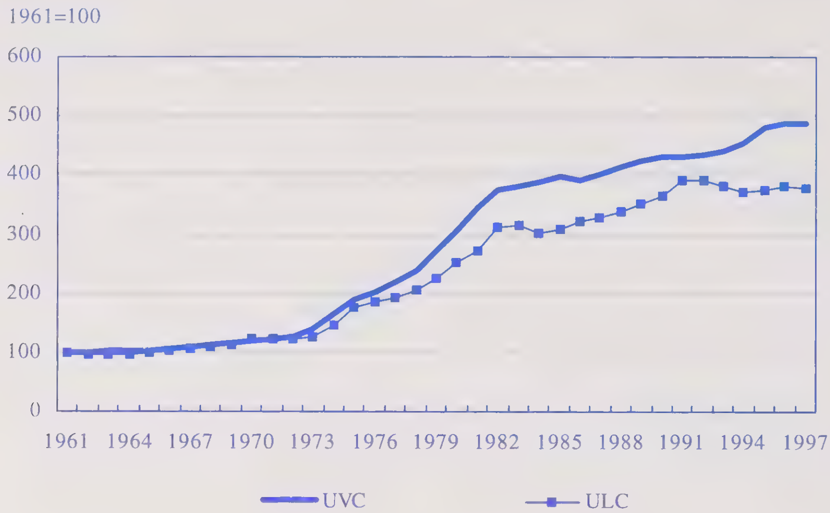
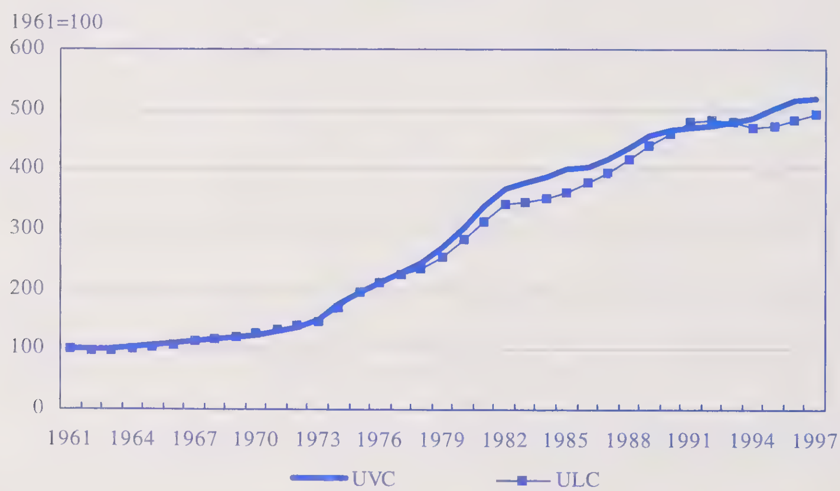


Figure 5.4 Unit Labour Costs and Unit Variable Costs in Business Sector, 1961-1997



The unit variable cost of production (UVC) represents the average variable cost of one unit of gross output. It is the ratio between all variable costs and real gross output,[3] and thus:

$$UVC = \frac{\text{Cost of labour} + \text{Cost of energy} + \text{Cost of raw materials} + \text{Cost of services}}{\text{Real gross output}} \quad (5)$$

5.5.1 Relationship Between the Two Indexes

The relationship between the ULC and the UVC in the business sector and the manufacturing sector in Canada is shown in Figures 5.3 and 5.4, which illustrate, in the form of indexes, how the ULC and the UVC evolved during the period 1961-1997.

An examination of these two figures reveals that apart from the period from 1991 to 1993, when the ULC and the UVC diverge somewhat, the two indexes evolve along similar lines throughout the period 1961-1997. In other words, they both move upward and downward at the same time, which suggests a strong correlation between the two trends.

The coefficient of correlation[4] of 0.99 estimated between the two unit cost measures, both for the business sector as a whole and for manufacturing, confirms the link illustrated in the two figures.

Cost measures are usually calculated in the form of indexes; but they are also often expressed in terms of growth rates. Fluctuations in the ULC and the UVC in the business sector and in manufacturing over the period from 1961 to 1997 are presented in Figures 5.5 and 5.6.

While the ULC and the UVC diverge for particular periods, these two figures reveal that the two measures exhibit almost identical trends for the study period as a whole.

Table 5.5 shows the average annual growth of the ULC and the UVC in the business sector and in manufacturing during the period 1961-1997. As may be seen, the two measures in the business sector increased at an almost identical rate throughout the period 1961-1997, that is, at an average annual rate of 4.7% for the UVC and 4.5% for the ULC.

During the period prior to 1973, the ULC and the UVC in the business sector increased on average at the same rate, that is, at an average annual rate of 3.3%. Starting in 1973, divergences began to appear between the growth rates of the UVC and the ULC. The ULC grew slightly more slowly than the UVC, except between 1983 and 1992 when the opposite occurred.

In the business sector, the UVC grew at annual rates averaging 10.6% during the period 1973-1979 and 8.5% during the period 1979-1983. In comparison, the ULC grew by respectively 9.5% and 7.9% during the same periods. The fact that the UVC grew more rapidly than the ULC between 1973 and 1983 has to do with exceptional events that marked that period, such as the substantial increases in the price of imported oil in 1973-1974 and 1979-1980. As a result of those increases, energy costs in the business sector rose 21.3% during the period 1973-1979 and by 15.0% between 1979 and 1983.

[3] When calculating the UVC, gross output in real terms is the relevant measure to use, since it includes all inputs, including labour and capital.

[4] The coefficient of correlation is calculated for the period 1961-1997.

Figure 5.5 Unit Labour Costs and Unit Variable Costs in Business Sector, 1962-1997

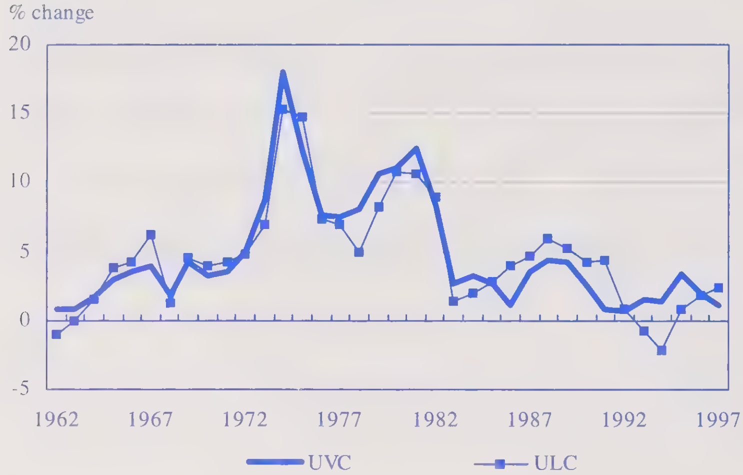


Figure 5.6 Unit Labour Costs and Unit Variable Costs in Manufacturing Sector, 1962-1997

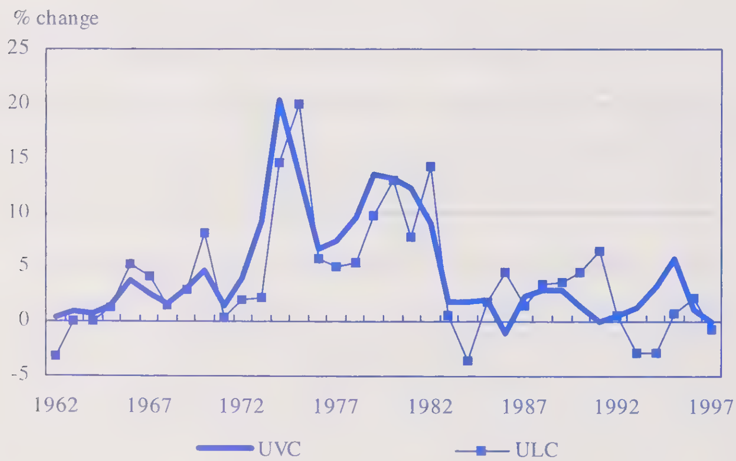


Table 5.5 Unit Labour Costs and Unit Variable Costs in the Business and Manufacturing Sectors, Average Annual Growth for Different Sub-periods Between 1961 and 1997

	Business Sector		Manufacturing Sector	
	UVC	ULC	UVC	ULC
	% change			
1961-1997	4.7	4.5	4.5	3.8
1961-1973	3.3	3.3	2.8	2.0
1973-1979	10.6	9.5	11.7	10.0
1979-1983	8.5	7.9	9.0	8.7
1983-1992	2.6	3.8	1.5	2.5
1992-1997	1.9	0.4	2.3	-0.7

These sizable increases drove up production and transportation costs for almost all products during these two periods.

Table 5.5 also shows that the average annual growth of the ULC in the business sector was greater than that of the UVC between 1983 and 1992 (3.8% versus 2.6%). This turnaround would appear to be largely attributable to a 9.0% drop in the cost of raw materials in 1991 and the collapse of oil prices in 1986 (-14.0%). During the period 1983-1992, the costs of raw materials and energy in the business sector increased respectively 3.5% and 2.3% annually, compared with an average annual growth rate of 6.4% for the cost of labour.

For the period 1992-1997, the UVC and the ULC grew more moderately than in previous periods. The average annual growth of the UVC was 1.9%, while that of the ULC was a mere 0.4%.

The manufacturing sector experienced a situation similar to that of the business sector in the evolution of the ULC and the UVC during the same periods, except for the period 1961-1973 when the UVC grew on average more rapidly than the ULC (2.8% per year versus 2.0%).

Clearly, the UVC is a more accurate indicator of short-term pressures on costs, but the ULC is still useful because of its strong correlation with the UVC and its timeliness. Statistics Canada's quarterly ULC is released two months after the end of the reference quarter, whereas the UVC cannot be measured until roughly 30 months later.

Given the strong positive correlation (very nearly 1) between the two cost measures and the greater timeliness of the ULC quarterly data, one of the advantages of the ULC indicator is that it can warn of pressures on costs in the business sector and in manufacturing much earlier than could be done with the UVC.[5]

[5] Other variants of variable costs can also be measured. Along the same lines, Dion and Fairclough (2000) recently looked at certain variants of unit costs. In their study, they present other measures of unit costs for the tradable goods sector and compare them to the ULC index for the manufacturing sector over the period 1961-1996. These authors find that the estimated indexes of unit labour costs in the tradable goods sector have profiles that are fairly similar to those of the ULC index for the manufacturing sector. The latter index could, to some extent, adequately represent the evolution of unit labour costs in the tradable goods sector.

5.6 The ULC as an Indicator of the Cost Competitiveness of the Business Sector

The concept of labour cost can provide an indicator of how competitive Canadian businesses are in relation to their foreign counterparts. To adequately exploit economies of scale, Canadian businesses are in fact increasingly dependent on foreign markets. What is meant by competitiveness? This often-used concept is frequently subject to controversy.

In general, competitiveness refers to the ability of a business, a group of businesses or a country to compete internationally. For the purposes of our analysis, we have adopted a definition focusing solely on costs. The business sector, for example, will be competitive if its unit costs are equal to or less than those of its competitors. Under these terms, competitiveness is determined by two different factors: Unit costs of production and the exchange rate.

Unit costs of production:

As explained above, when a business's unit costs—notably labour costs—increase, this generally results in an increase in the price of its products. All things being equal, those products then sell for more than the products of its competitors.

The exchange rate:

The exchange rate makes it possible to compare prices and costs between two countries in a common currency. Exporting businesses must frequently deal with changes in the exchange rate, since these changes affect the price of goods sold abroad. In the case of a depreciating Canadian dollar, Canadian products become relatively cheaper on external markets. Foreign products become more expensive in Canadian markets.

These two components may evolve differently and either offset or reinforce each other. For example, if the Canadian dollar loses value against the U.S. dollar and if a business makes productivity gains that translate into lower unit costs of production, then the price of its products for export will be subject to two downward pressures, which should enable it to sell more on the U.S. market. As a result, it is in a better position to export.

If we want to assess the competitive position of Canadian businesses in relation to their U.S. competitors, we can evaluate it approximately by comparing the evolution of relative labour costs using the following formula:

$$(\Delta HW_{CAN} - \Delta HW_{US}) - (\Delta LP_{CAN} - \Delta LP_{US}) + \Delta e = \Delta ULC_{CAN_{US\$}} - \Delta ULC_{US}$$

where HW is the hourly wage, LP is labour productivity, e is the exchange rate and ULC is the unit labour cost.

The change in the relative cost of labour expressed in a common currency (in this case, the U.S. dollar) introduces three components that can have an impact on competitiveness between two countries:

(1) the relative evolution of the hourly wage;

(2) the difference in productivity gains between the two countries;

(3) the exchange rate, (which by giving the value of the Canadian dollar in U.S. dollars, makes it possible to make cost comparisons in a common currency).

Table 5.6 Canada-U.S. Comparison of the Evolution of the ULC in Manufacturing, 1992-2000*

	Canada	United States**	Gain or Loss for Canada
	Variation over the period (%)		
Labour Productivity	16.5	44.7	28.2 (loss)
Hourly Compensation	17.0	30.1	13.1 (gain)
ULC in CAN$	0.6	–	–
ULC in US$	-18.3	-10.1	8.2 (gain)
Depreciation of Canadian Dollar	18.6	–	18.6 (gain)

* In this particular instance, the data incorporate the treatment of software expenditures in the manufacturing sector as investment in the measurement of output. In incorporating this change, Canada is conforming to U.S. practice. This improves the comparability of the productivity measure and the ULC with that published by the U.S. Bureau of Labor Statistics.

** Source: U.S. Bureau of Labor Statistics.

An improvement of Canada's competitive position in relation to the United States may therefore come from:

– a reduction in domestic ULCs (as a result of a more rapid growth in productivity or a slower increase in wages);

– a rise in labour costs in the United States;

– a depreciation of the Canadian dollar in relation to the U.S. dollar.

Considering that in 2000, the U.S. market was the destination of 85.1% of Canadian merchandise exports, it is useful to compare the competitive position of the two countries' manufacturing sectors. Data on unit labour costs in the manufacturing sector are more suitable for evaluating the competitiveness of tradable goods produced in Canada, since services are not traded internationally to the same extent.

Table 5.6 compares evolution of unit labour costs in Canada and the United States between 1992 and 2000. As the table shows, there was an improvement in the unit labour costs of Canadian manufacturing industries in relation to their U.S. counterparts.

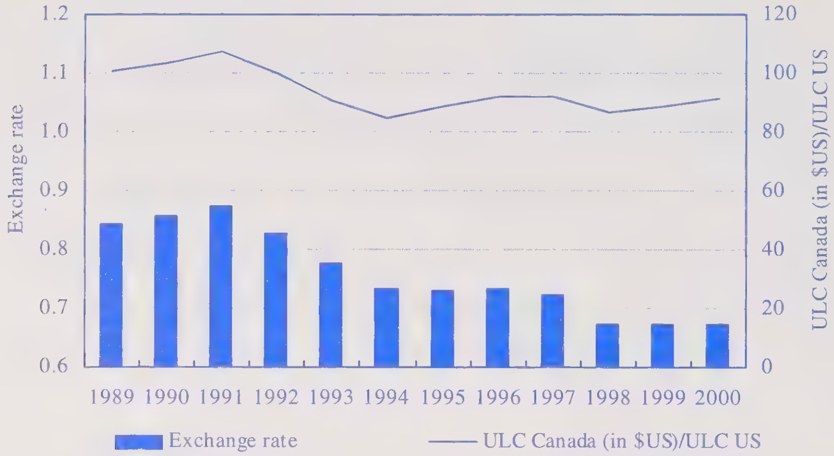
The ULC for the Canadian manufacturing sector, as expressed in U.S. dollars, declined 18.3% between 1992 and 2000. The American ULCs, for their part, declined 10.1% during the same period. Thus, Canada enjoyed an improvement in its relative unit labour costs in the manufacturing sector.

Despite this improvement in competitiveness, Canadian manufacturers have not done as well with respect to productivity as have their competitors in the United States over the same period. Between 1992 and 2000, the increase in productivity in the Canadian manufacturing sector (16.5%) was on average lower than that in the American manufacturing sector (44.7%).

At the same time, the hourly compensation paid to workers in the manufacturing sector increased less rapidly in Canada than in the United States. Over the period 1992-2000, it grew by only 17.0% in Canada, while it climbed 30.1% in the United States. As a result, the 28% gap in productivity growth in favour of American manufacturers was partially offset by lower wage growth (-13%) in Canada.

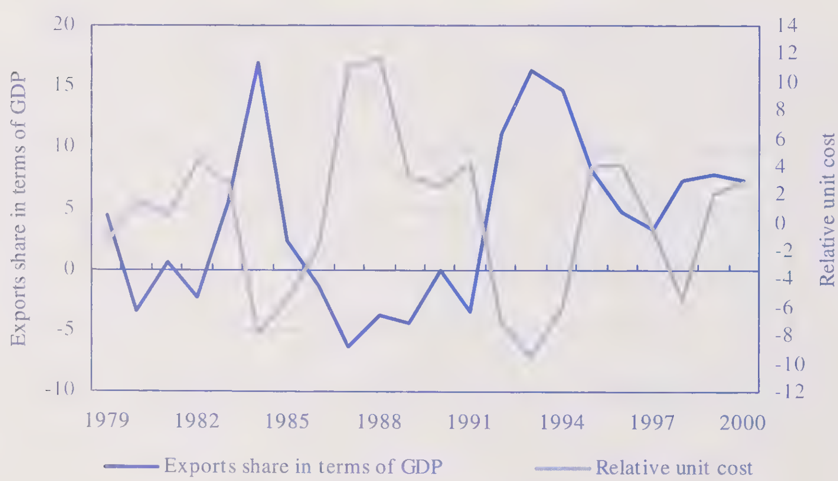
Between 1992 and 2000, the Canadian dollar lost value against the U.S. dollar, going from US$0.82 in 1992 to US$0.67 in 2000, a loss of 18.6% of its value (Figure 5.7).

Figure 5.7 Exchange Rate and Relative Labour Costs in the Manufacturing Industries, Canada- United-States: 1989-2000 (1992=100)



* The data used here also incorporate the treatment of software expenditures in the manufacturing sector as investment in the measurement of output. The U.S. data are from the U.S. Bureau of Labor Statistics.

Figure 5.8 Exports Share in Terms of GDP and Relative Unit Cost, 1979-2000 (percent change)



* The **relative unit cost** is defined as the difference between the growth rates of the unit labour cost in Canada and the United States, with these costs being expressed in U.S. dollars for purposes of comparison. A negative rate for the relative unit cost indicates an improvement in the competitiveness of the Canadian manufacturing sector.

Ultimately, this was what enabled Canadian manufacturers to maintain their competitiveness. In other words, the improvement in the performance of the Canadian manufacturing sector in the U.S. market was not due to higher productivity gains than our U.S. partners; rather it was due to slower wage growth (-13%) and the depreciation of the Canadian dollar in relation to its U.S. counterpart (-19%).

5.6.1 Exports Are Sensitive to Changes in Unit Costs

Since it has a limited domestic market, Canada depends greatly on international trade. Most of our merchandise trade, in both imports and exports, is with the United States. In 2000, 85.1% of all Canadian merchandise exports went to the U.S. market.

The evolution of ULCs is one of the factors that determines the competitiveness of Canadian-manufactured goods on the international market. A stabilization or even a decrease in labour costs enables businesses to keep their prices competitive internationally. This favours an increase in exports.

The improvement of the cost competitiveness of Canadian manufacturing industries has probably helped bolster exports since 1992 (Figure 5.8). Exports of merchandise to the U.S. market increased substantially during this period. More specifically, the exports of Canadian manufacturing businesses grew by an average of 14.3% per year during the period 1992-2000. The gradual adoption of the North American Free Trade Agreement and the robust and uninterrupted growth of the U.S. economy in the 1990's have also contributed to the surge in Canadian exports to the United States. This long-term trend was encouraged by a substantial growth in the U.S. economy. But deviations around the trend were closely related to changes in unit labour costs, as Figure 5.8 shows.

5.7 The Relationship Between Relative Unit Cost and Export Growth, by Manufacturing Industry Group

In order to better understand the relationship between unit labour costs and export success, we examine the relationship between the relative unit cost in the manufacturing sector of Canada and the United States and exports as a proportion of the GDP on an industry-by-industry basis.

The relative unit cost and Canadian exports are examined for 19 industry groups in the manufacturing sector in Canada and the United States. For both countries, the manufacturing sector includes the forest industry, which in Canada's case has included the wood industry for purposes of comparison.

Each industry's share of Canadian manufacturing exports is presented in Table 5.7 for 1981 and 1997. Transportation equipment industries account for the largest proportion (approximately one-third in 1997) of all manufacturing exports. In 1997, electrical and electronic products (9.4%), followed by paper and allied products (9.2%) and primary metal (8.4%), also accounted for a major proportion of Canadian exports of manufactured products.

Between 1981 and 1997, transportation equipment and electrical and electronic products increased their share of exports (by 22% and 75% respectively). On the other hand, during the same period, exports of the paper and allied products and primary metal industries declined in importance; their proportional shares decreased by 42.5% and 35.0% respectively. The shares of other groups of manufacturers ranged between 0.1% for tobacco industries and 7.6% for wood industries.

Table 5.7 Industry Share of Total Manufacturing Exports,* 1981 and 1997		
Industry	1981	1997
	%	
Transportation Equipment	26.8	32.8
Electrical and Electronic Products	5.4	9.4
Paper and Allied Products	16.0	9.2
Primary Metal	12.9	8.4
Wood	6.6	7.6
Chemical and Chemical Products	6.6	6.1
Food and Beverage	6.8	5.1
Machinery Industries (except electrical machinery)	5.9	4.9
Fabricated Metal Products	2.2	2.8
Refined Petroleum and Coal Products	4.6	2.7
Plastic and Rubber Products	1.3	2.6
Other Manufacturing	1.6	2.5
Furniture and Fixture	0.5	1.9
Clothing and Textile Products	0.6	1.2
Non-metallic Mineral Products	1.0	1.1
Primary Textile	0.5	0.8
Printing, Publishing and Allied	0.4	0.6
Leather and Allied Products	0.2	0.1
Tobacco	0.2	0.1

* Data source: International Trade Division of Statistics Canada.

In general, when we compare relative ULCs with exports by industry, we observe an inverse relationship between these two variables (see figures in Appendix 5.B). As the Canada/U.S. relative unit cost decreases, exports rise. Of course, there are exceptions for some industries, but on the whole, this inverse relationship appears to be confirmed.

As seen above, changes in the relative unit cost result directly from three factors: the increase in relative hourly compensation (the difference in the growth of compensation between Canada and the United States), the relative growth of labour productivity (the difference in labour productivity growth between Canada and the United States), and the exchange rate for the Canadian dollar in relation to its U.S. counterpart (which allows comparisons in the same currency). All things being equal, a decrease in the relative unit cost in a given industry will result in a decrease in the relative prices of the goods and services that it produces, which should in turn lead to an increase in the demand for these products on external markets.

In order to better identify the relationship between relative ULCs and export growth, the coefficient of correlation between these two variables was calculated for the 19 industry groups. For 16 of them, negative coefficients of correlation were obtained (see Table 5.8). The three exceptions were manufacturers of metal products, refined petroleum and coal products and primary metals, which posted coefficients of correlation of 0.0, 0.33 and 0.42 respectively.

For a number of industries, the coefficient of correlation is negative and highly significant. This indicates that there is a negative relationship between relative unit labour costs and exports, but the strength of this relationship differs from one industry to another. Lumber (-0.73), clothing and textile products (-0.65), plastic and rubber products (-0.65), paper and allied products (-0.63), printing and publishing (-0.61) and non-metallic mineral products (-0.60) are among the Canadian industries most sensitive to changes in relative ULCs.

Table 5.8 Correlation between Export Growth and Relative Unit Cost, by Manufacturing Industry,* 1982-1997

Industry	Coefficient of Correlation
Wood	-0.73 ***
Clothing and Textile Products	-0.65 ***
Plastic and Rubber Products	-0.65 ***
Paper and Allied Products	-0.63 ***
Printing, Publishing and Allied	-0.61 ***
Non-metallic Mineral Products	-0.60 ***
Machinery Industries (except electrical machinery)	-0.52 ***
Food and Beverage	-0.44 ***
Primary Textile	-0.42 ***
Furniture and Fixture	-0.40
Other Manufacturing**	-0.38
Leather and Allied Products	-0.38
Chemical and Chemical Products	-0.33
Tobacco	-0.24
Transportation Equipment	-0.21
Electrical and Electronic Products**	-0.15
Fabricated Metal Products	-0.02
Refined Petroleum and Coal Products	0.33
Primary Metal	0.42

* Source of U.S. data: U.S. Bureau of Economic Analysis and U.S. Bureau of Labor Statistics.

** For the electrical and electronic products industries and other manufacturing industries, the coefficient of correlation between the variables is calculated for the period 1988-1997.

*** Significantly different from zero.

The coefficients of correlation of the other industry groups vary between -0.15 for electrical and electronic products industries and -0.52 for machinery industry (except electrical machinery). Transportation equipment industries, which account for a third of exports of all manufacturing industries combined, are less sensitive to changes in the relative ULC. The same is true for electrical and electronic products and metal products. Lastly, the positive relationship observed between the relative ULC and changes in exports for refined petroleum products and less processed metals seems to indicate that factors other than labour cost differences are at play for these industries.

5.8 Summary and Conclusion

In this chapter, we have reviewed the basic concepts needed to understand the notion of unit labour cost. The ULC indicator was compared with a broader measure, the UVC, which represents all variable costs of inputs used in production. A very strong correlation between the two cost measures was observed during the period 1961-1997, not only in the business sector but also in manufacturing. The ULC provides a timely indicator of short-term pressures on variable costs.

We then described the usefulness of the ULC and the main factors that affect its evolution. By making comparisons with the ULC in the United States, we examined the role of the ULC as an indicator of competitiveness and as a factor behind the observed upward trends in Canadian exports over the 1992-2000 period.

By measuring the cost competitiveness of the manufacturing sector in terms of relative unit labour costs, we outlined the advantage that has developed for Canadian manufacturers. The gap in unit costs between the two countries, expressed in U.S. dollars, has developed in Canada's favour since1992. However, this competitive advantage in relation to the United States is not due to productivity gains; these lag behind those recorded in the United States; instead, it is due to the weakness of the Canadian dollar and lower wage rates.

We also examined in greater detail the link between the evolution of the relative unit cost and export growth for 19 comparable industry groups. Coefficients of correlation between the relative unit cost and export growth were negative for 90% of the industry groups. There is an inverse relationship between changes in relative costs and the evolution of exports, but the scope of this relationship differs from one industry to another.

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Appendix 5.A—A Brief Overview of Concepts of Costs in a Business

Total Cost of Production in Businesses

The concept of cost is central to a business's economic accounting. In general, cost refers to the expense that the business incurs in its production. It is an important concept, since knowledge thereof enables the business to set the selling price of the goods and services that it produces in order to cover its costs. In accounting terms, it is the difference between the receipt from sales and the total cost (all expenses incurred) which, among other things, makes it possible to provide compensation for consultants' services, a fund for new production equipment and dividends for the capital used.

The cost of production, which is made up of all the costs generated in producing a product intended for sale, generally corresponds to the total cost of all the activities of the business. Thus, the cost of production is defined as the sum of expenditures relating to the manufacture and sale of the good or service produced. Depending on the analytical viewpoint, a distinction is sometimes made between the cost of production, including the cost of acquisition of raw materials and intermediate goods as well as the manufacturing cost (wage costs and miscellaneous expenses) and the distribution cost, which consists of the expenses associated with selling (distribution network, advertising, etc.).

Fixed Costs, Variable Costs and Unit Variable Cost of Production

Generally, two components of the total cost of production are distinguished. The fixed cost (FC), which is a basic cost, is independent of the short-term level of production. In general, it corresponds to the costs of maintaining equipment (whether it is being operated or not), its financial depreciation, various types of insurance, the salaries of management, administration, office and sales staff and various overhead costs. In some industries, such as the motor vehicle and aircraft industries, fixed costs are very significant because of the activities of these industries that require sizable prior expenditures on research and capital investment.

On the other hand, the other component, the variable cost (VC), as its name indicates, varies in the short run according to the volume of activity. Labour, raw materials, energy and the services used in the production process are examples of expenses included in variable costs. Some components of the variable cost vary proportionally to the quantity produced, such as raw materials and intermediate goods; others increase at a different rate, such as the labour cost when there is overtime, since the latter is generally paid at a higher rate.

The total cost of production (TC) may be written as follows: TC = FC + VC

If we know the total cost of production and the units produced (Q), we can calculate the *unit cost of production, as follows*:

$$UCP = \frac{TC}{Q} \quad ;$$

The *unit variable cost* (or *average variable cost*) may also be calculated by taking the ratio between the variable cost and the quantities produced, as follows:

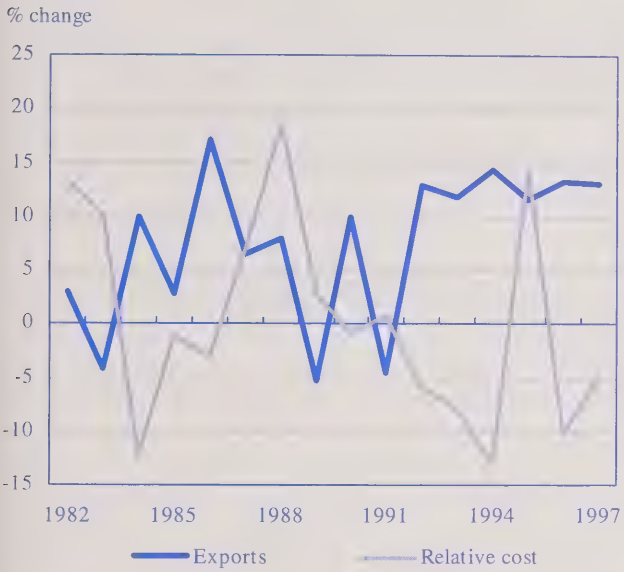
$$UVC = \frac{VC}{Q} \quad .$$

Labour Cost

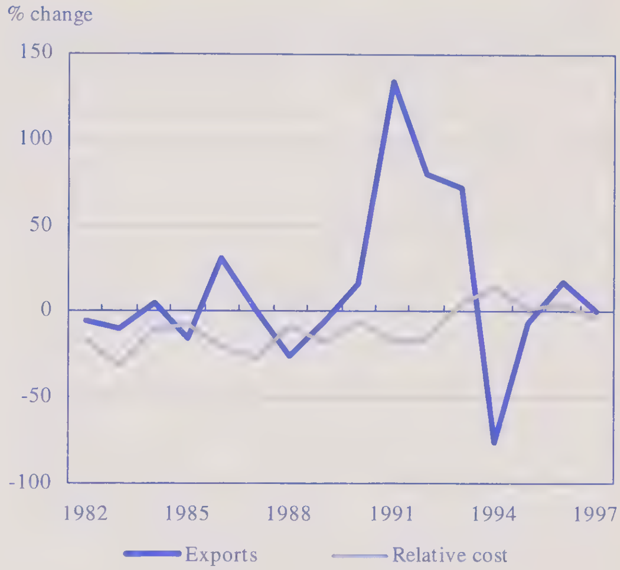
Here, the concept of labour cost refers to all expenses borne by employers for the use of labour. Wages are paid by businesses in the form of gross compensation (gross wages). Compensation for overtime is also taken into account. However, the wage cost or the total compensation of labour does not consist solely of wages but also includes fringe benefits. These are divided into three main components: time compensated but not worked, private or public insurance, and private or public pension funds. The costs of fringe benefits borne by Canadian businesses can represent up to a third of the average compensation of employees. Thus, the labour cost is made up of gross wages plus fringe benefits. For the purposes of productivity measures, total labour costs should include not only compensation of the labour of employees, but also compensation of the labour of self-employed workers.

Appendix 5.B—Exports and Relative Unit Cost by Manufacturing industry 1982-1997

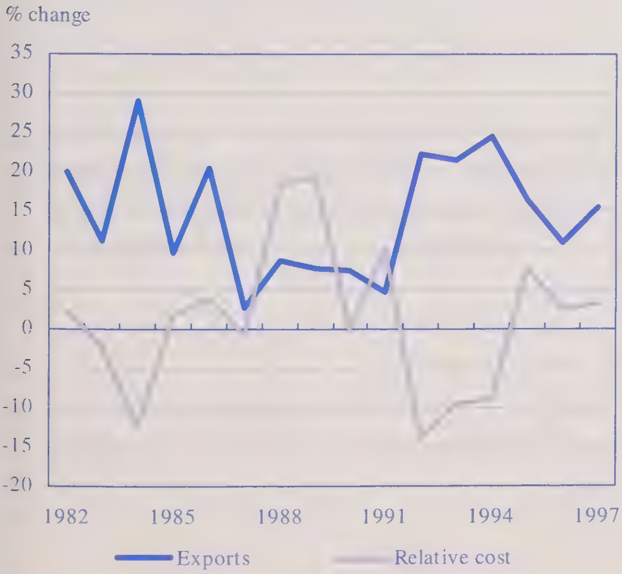
Food and Beverage Industries, 1982-1997



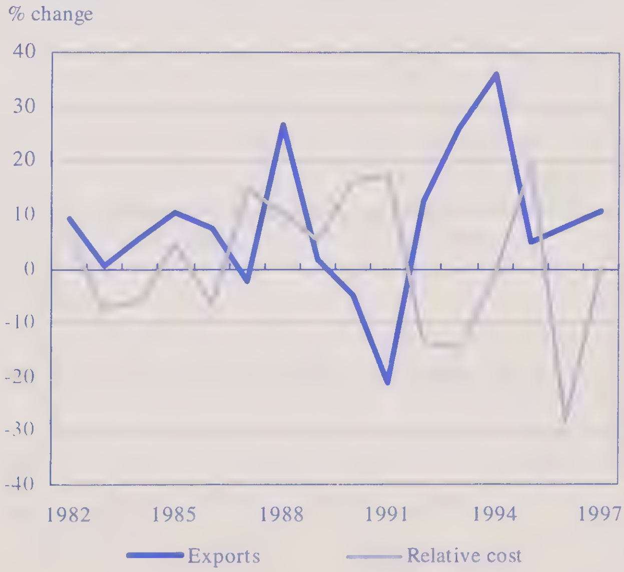
Tobacco Products Industry, 1982-1997



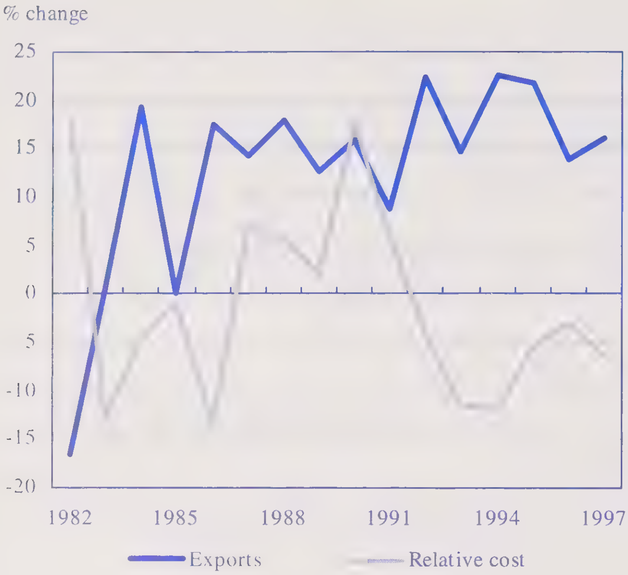
Rubber and Plastic Products, 1982-1997



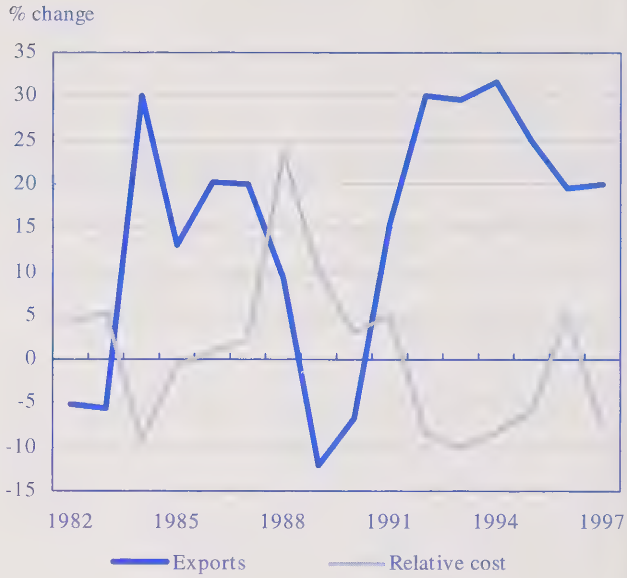
Leather and Allied Products Industries, 1982-1997



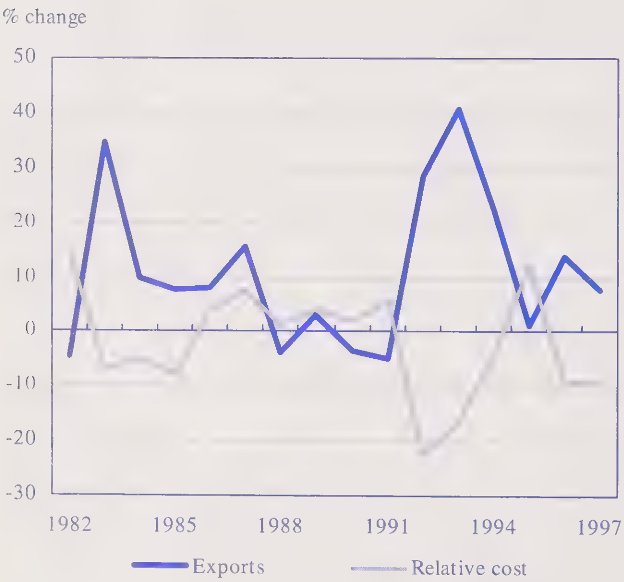
Primary Textile Industries, 1982-1997



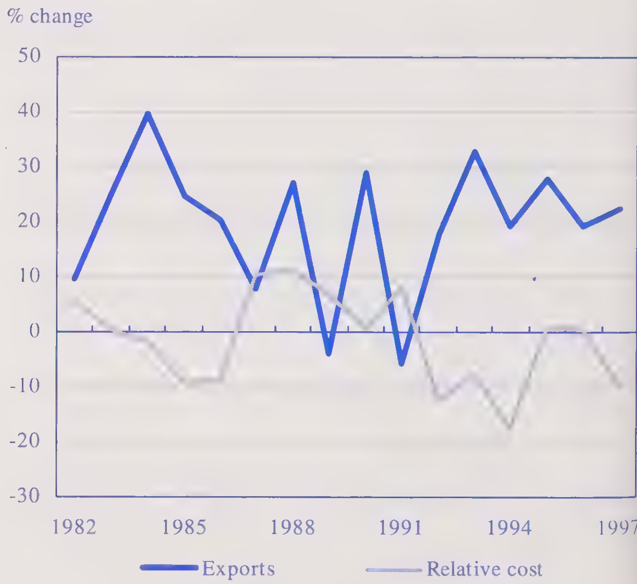
Clothing and Other Textile Products, 1982-1997



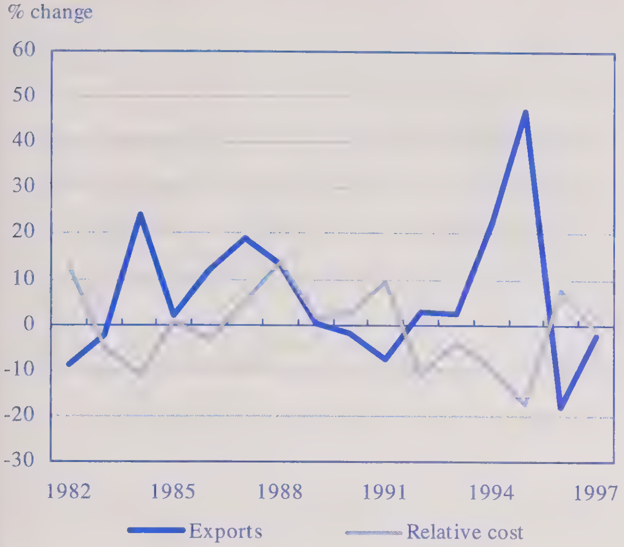
Wood Industries, 1982-1997



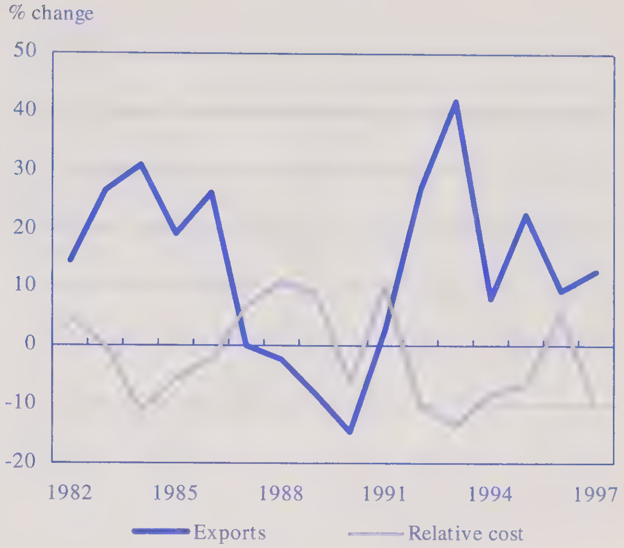
Furniture and Fixture Industries, 1982-1997



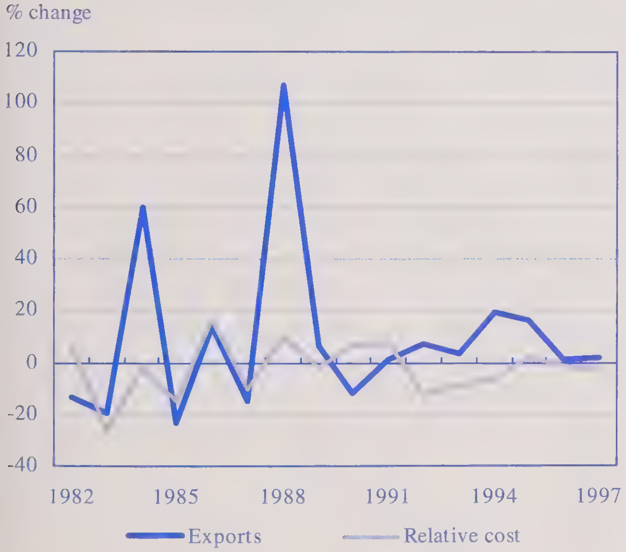
Paper and Allied Products Industries, 1982-1997



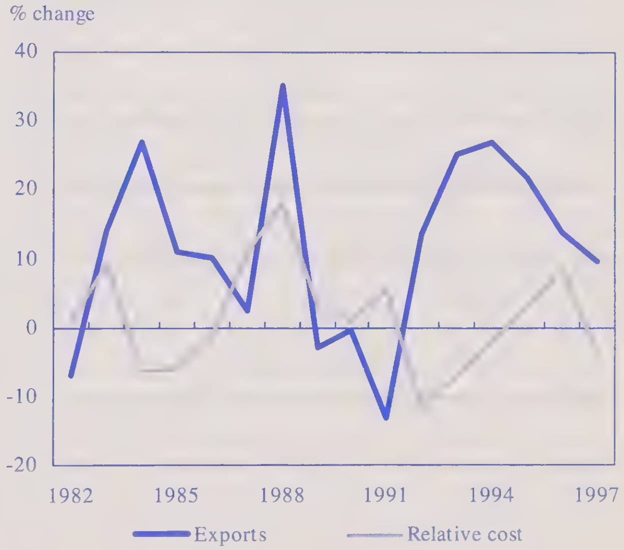
Printing, Publishing and Allied Industries, 1982-1997



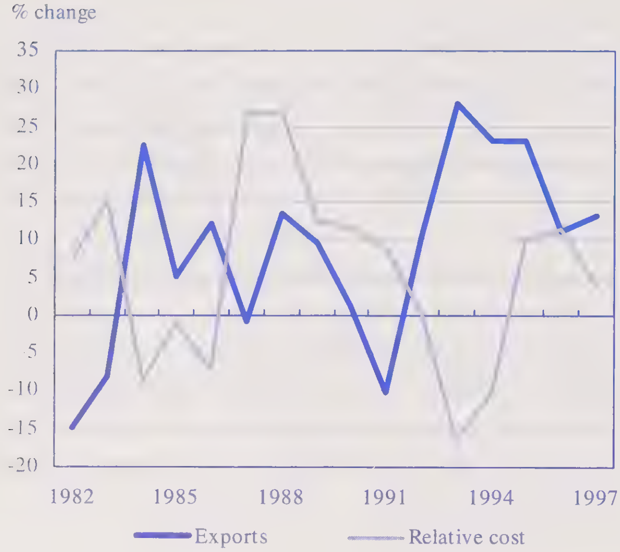
Primary Metal Industries, 1982-1997



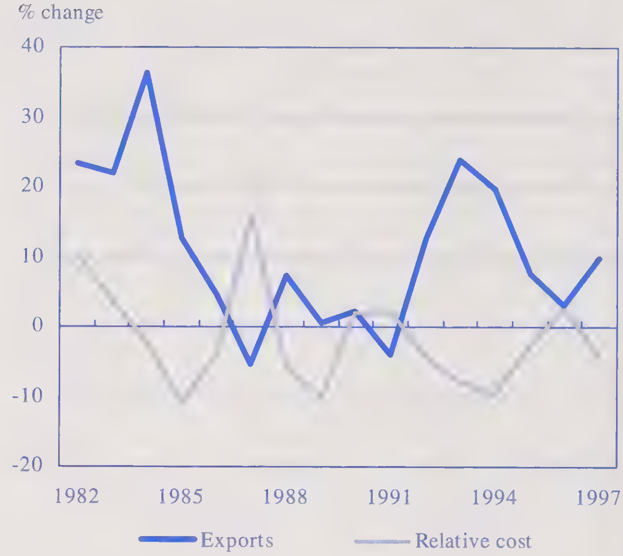
Fabricated Metal Products Industries, 1982-1997



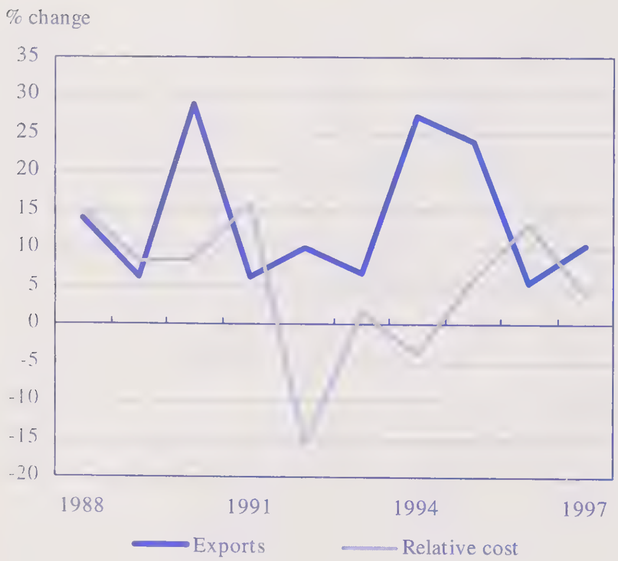
Machinery Industries (except electrical machinery), 1982-1997



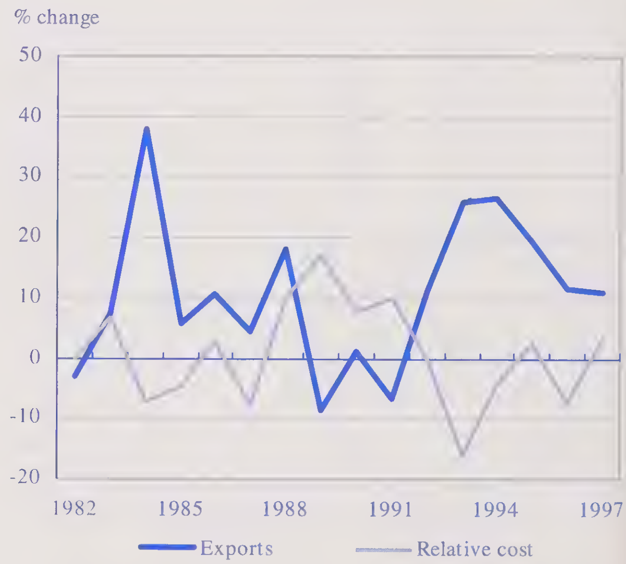
Transportation Equipment Industries, 1982-1997



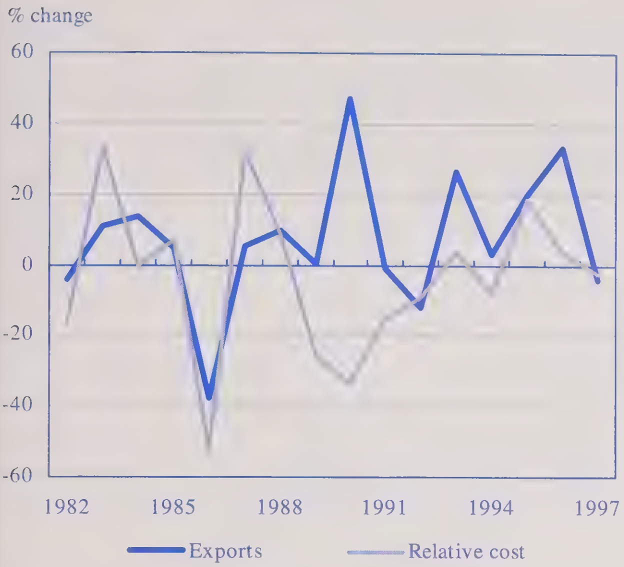
Electrical and Electronic Products Industries, 1988-1997



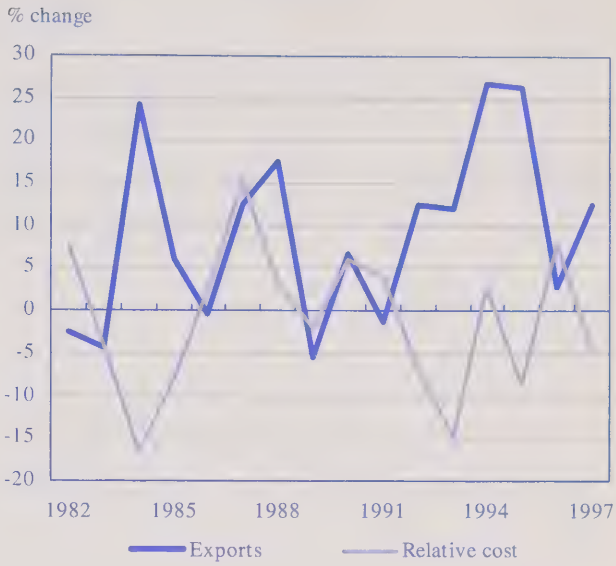
Non-metallic Mineral Products Industries, 1982-1997



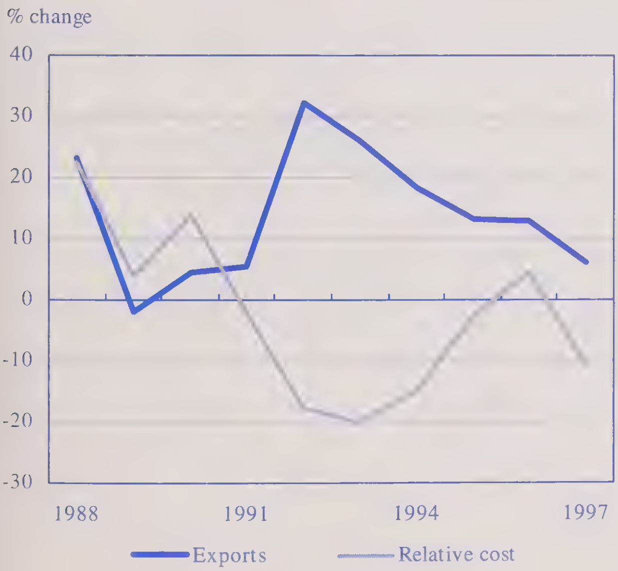
Refined Petroleum and Coal Products Industries, 1982-1997



Chemical and Chemical Products Industries, 1982-1997



Other Manufacturing Industries, 1988-1997



Data Appendix—Productivity Series and Related Measures

Methodological note

These tables present data for the business sector and its 16 major sectors based on the 1980 standard industrial classification. The business sector includes all of gross domestic product except the output of general government, non-profit institutions and the rental value of owner-occupied real estate.

For the business sector productivity measures, output is measured as real GDP—deliveries in constant chained dollars of final goods and services by the business sector to domestic households, investment, government and non-profit institutions, and net exports to other countries. Business sector GDP series reported in the 2001 edition of this publication were based on an aggregation of real value added across industries. At the industry level, output is defined in terms of real value added. Real value added series reflect both the real contribution of capital and labour in converting intermediate inputs into finished products by industry. The estimates of output reflect the capitalization of software expenditures.

Capital input services measure the services derived from the stock of physical assets and software. The assets included are fixed business equipment, structures, inventories, and land. The 2001 edition of this publication used capital stock.

Labour input services are obtained by aggregation of the hours worked by all persons, classified by education and work experience with weights determined by their shares of labour compensation. The 2001 edition of this publication used the sum of hours at work.

Capital-labour ratio is the ratio of capital services to hours worked.

Multifactor productivity is measured as the ratio of output per unit of combined inputs (capital services and labour services). Labour productivity is measured as output per hour worked.

Capital productivity is measured as output per unit of capital services.

Combined inputs. Labour input combined with capital input, using labour's and capital's share of costs as weights to form a Fisher chained index.

Total compensation per hour is measured as the ratio of labour compensation for all jobs to the number of hours at work.

Unit labour cost is the ratio of labour compensation per unit of real GDP.

Table 1a. Productivity and Related Measures, 1981-2000, Index 1997=100

	Business Sector										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	66.1	80.7	98.7	81.5	70.3	61.2	66.7	76.3	108.2	52.1	63.6
1982	62.8	76.7	95.2	81.6	67.5	62.8	65.8	82.1	100.2	57.3	70.0
1983	64.8	76.7	96.9	84.1	68.1	64.1	66.6	83.8	101.1	59.8	70.8
1984	69.7	79.1	101.4	87.9	70.6	65.6	68.7	83.1	106.6	62.9	71.3
1985	73.3	82.4	102.2	88.6	73.9	68.0	71.6	82.6	108.1	65.8	74.0
1986	75.1	85.2	100.8	88.0	77.0	70.4	74.5	82.9	106.9	68.0	77.1
1987	79.0	88.7	101.0	88.8	80.7	73.7	78.0	83.3	107.4	71.6	80.3
1988	82.9	92.6	100.7	89.4	85.2	77.5	82.2	83.9	107.3	76.0	84.8
1989	84.8	94.7	99.1	89.4	87.8	81.5	85.4	86.3	104.2	80.0	89.4
1990	83.7	94.2	96.6	88.6	87.8	84.0	86.4	89.4	99.6	83.5	94.0
1991	79.9	90.2	93.4	88.5	85.2	85.7	85.4	95.1	93.1	88.0	99.3
1992	80.3	88.5	93.9	90.5	84.6	86.7	85.3	97.9	92.4	90.9	100.2
1993	82.7	89.8	94.6	91.8	87.1	87.5	87.2	97.3	94.4	91.5	99.4
1994	88.6	92.9	98.1	95.3	90.8	89.7	90.3	96.5	98.8	91.6	95.9
1995	92.1	94.4	99.4	97.6	92.9	92.3	92.7	97.8	99.8	94.0	96.3
1996	94.4	96.8	98.7	97.4	95.8	95.2	95.6	98.3	99.1	95.5	98.0
1997	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998p	104.5	102.8	101.0	101.7	102.7	104.7	103.5	102.0	99.8	103.9	102.2
1999p	111.5	106.8	103.8	104.6	106.5	109.4	107.6	102.6	102.0	105.0	100.5
2000p	117.5	110.0	105.1	107.0	110.8	113.9	112.0	103.7	103.3	111.4	104.3

p The symbol p means that the series are preliminary.

Table 1b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Business Sector										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-4.9	-5.1	-3.5	0.1	-3.9	2.5	-1.4	7.6	-7.4	10.1	9.9
1983	3.1	0.0	1.8	3.1	0.8	2.2	1.3	2.1	0.9	4.3	1.2
1984	7.7	3.2	4.6	4.5	3.7	2.2	3.1	-0.9	5.4	5.1	0.7
1985	5.1	4.3	0.8	0.8	4.7	3.7	4.3	-0.6	1.4	4.6	3.8
1986	2.5	3.3	-1.4	-0.8	4.2	3.6	4.0	0.3	-1.1	3.4	4.2
1987	5.1	4.1	0.3	1.0	4.9	4.7	4.8	0.6	0.4	5.2	4.2
1988	5.0	4.4	-0.3	0.6	5.5	5.1	5.3	0.7	-0.1	6.2	5.6
1989	2.3	2.3	-1.6	-0.1	3.1	5.1	3.9	2.8	-2.8	5.3	5.4
1990	-1.4	-0.6	-2.5	-0.8	0.0	3.1	1.2	3.7	-4.5	4.3	5.2
1991	-4.4	-4.2	-3.3	-0.2	-3.0	2.1	-1.2	6.3	-6.5	5.4	5.6
1992	0.4	-1.8	0.5	2.3	-0.7	1.1	-0.1	3.0	-0.7	3.2	0.9
1993	3.0	1.5	0.8	1.5	3.0	0.9	2.2	-0.6	2.1	0.7	-0.8
1994	7.2	3.4	3.6	3.8	4.1	2.5	3.6	-0.9	4.7	0.0	-3.5
1995	3.9	1.6	1.4	2.3	2.3	2.9	2.6	1.3	1.0	2.7	0.4
1996	2.4	2.6	-0.7	-0.1	3.2	3.1	3.1	0.5	-0.7	1.6	1.7
1997	6.0	3.3	1.4	2.6	4.3	5.1	4.6	1.8	0.9	4.7	2.1
1998[p]	4.5	2.8	1.0	1.7	2.7	4.7	3.5	2.0	-0.2	3.9	2.2
1999[p]	6.7	3.9	2.7	2.8	3.6	4.5	4.0	0.6	2.2	1.0	-1.7
2000[p]	5.3	3.0	1.3	2.3	4.1	4.1	4.1	1.1	1.3	6.2	3.8

[p] The symbol p means that the series are preliminary.

Table 2a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Agriculture and Related Services										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	70.2	108.1	65.9	65.5	90.4	129.2	107.6	120.4	55.4	49.4	76.0
1982	72.7	108.5	68.0	67.5	91.9	128.2	107.9	118.9	57.8	52.6	78.5
1983	69.5	106.1	66.0	66.0	90.2	126.4	106.2	119.9	56.0	56.2	85.8
1984	68.2	106.3	64.9	64.7	91.3	124.9	106.1	118.2	55.7	57.3	89.3
1985	71.2	110.5	67.1	64.9	95.9	121.8	107.2	110.6	59.5	59.9	93.0
1986	81.4	108.8	78.0	75.3	94.5	118.9	105.1	109.7	69.5	62.4	83.4
1987	76.8	106.8	75.1	72.4	93.7	115.3	103.0	108.4	67.6	65.8	91.5
1988	70.0	104.3	69.8	67.7	93.5	111.3	101.3	107.2	64.0	70.9	105.5
1989	81.3	103.2	82.1	79.3	93.8	107.1	99.7	104.2	76.7	75.3	95.6
1990	94.9	102.6	98.0	93.0	92.8	102.5	97.0	100.4	92.8	78.3	84.7
1991	96.0	95.9	103.3	100.2	87.9	99.5	93.0	104.0	96.7	81.5	81.4
1992	88.3	98.0	93.8	90.0	91.6	96.9	94.0	99.0	91.4	83.5	92.7
1993	95.0	99.9	99.0	95.0	95.3	96.6	95.9	96.7	98.6	85.9	90.4
1994	96.4	99.8	99.2	96.5	97.6	96.4	97.2	96.7	100.3	91.5	94.8
1995	99.3	98.4	102.7	100.8	96.8	96.3	96.7	97.9	103.4	92.4	91.6
1996	104.9	100.6	106.3	104.2	100.5	96.5	98.7	96.0	109.0	96.2	92.3
1997	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998p	106.2	96.3	105.0	110.0	98.8	104.7	101.2	108.4	101.6	112.0	101.5
1999p	115.6	90.7	115.9	125.9	93.7	107.7	99.6	117.8	107.5	108.8	85.4
2000p	113.0	87.4	119.3	127.9	83.2	110.9	94.5	125.6	102.0	106.8	82.6

p The symbol p means that the series are preliminary.

Table 2b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Agricultural and Related Services										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	3.5	0.4	3.2	3.0	1.7	-0.8	0.2	-1.3	4.3	6.3	3.3
1983	-4.4	-2.2	-2.9	-2.2	-1.8	-1.4	-1.6	0.9	-3.1	6.8	9.3
1984	-1.7	0.2	-1.7	-1.9	1.2	-1.2	-0.1	-1.4	-0.5	2.1	4.1
1985	4.3	3.9	3.3	0.3	5.0	-2.5	1.0	-6.4	6.7	4.5	4.1
1986	14.4	-1.6	16.3	16.0	-1.4	-2.4	-2.0	-0.8	16.8	4.3	-10.3
1987	-5.6	-1.8	-3.7	-3.8	-0.8	-3.0	-1.9	-1.1	-2.6	5.4	9.6
1988	-8.9	-2.3	-7.1	-6.5	-0.2	-3.5	-1.7	-1.2	-5.4	7.7	15.4
1989	16.1	-1.0	17.7	17.1	0.3	-3.8	-1.6	-2.7	19.8	6.2	-9.4
1990	16.7	-0.6	19.3	17.3	-1.1	-4.3	-2.6	-3.7	21.0	4.1	-11.4
1991	1.2	-6.5	5.4	7.8	-5.3	-3.0	-4.2	3.5	4.2	4.1	-3.9
1992	-8.1	2.2	-9.2	-10.3	4.3	-2.6	1.1	-4.7	-5.5	2.5	14.0
1993	7.6	2.0	5.5	5.6	4.0	-0.4	2.0	-2.3	7.9	2.8	-2.5
1994	1.5	-0.1	0.2	1.6	2.4	-0.2	1.3	-0.1	1.7	6.5	4.8
1995	3.0	-1.4	3.5	4.4	-0.8	-0.1	-0.5	1.3	3.1	1.0	-3.4
1996	5.7	2.2	3.5	3.4	3.8	0.3	2.1	-2.0	5.4	4.1	0.7
1997	-4.7	-0.6	-6.0	-4.1	-0.5	3.6	1.3	4.2	-8.2	4.0	8.4
1998p	6.2	-3.7	5.0	10.0	-1.2	4.7	1.2	8.4	1.6	12.0	1.5
1999p	8.8	-5.7	10.4	14.5	-5.1	2.9	-1.6	8.7	5.8	-2.9	-15.8
2000p	-2.2	-3.7	2.9	1.5	-11.2	2.9	-5.1	6.6	-5.1	-1.8	-3.3

p The symbol p means that the series are preliminary.

Table 3a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Fishing and Trapping										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	117.5	90.0	x	167.2	80.6	127.8	112.7	186.6	93.9	33.8	25.9
1982	126.3	90.9	x	178.1	82.3	119.8	108.1	173.1	106.8	36.1	26.0
1983	122.0	94.1	x	165.7	85.6	110.0	102.8	152.7	112.0	36.1	27.9
1984	109.7	98.0	x	142.2	89.4	99.8	97.3	132.5	111.0	38.0	33.9
1985	128.6	95.9	x	169.7	88.1	94.3	93.1	127.9	136.3	53.1	39.6
1986	133.0	105.5	x	158.6	97.6	92.6	95.3	112.8	143.4	58.0	46.0
1987	114.2	111.0	x	127.9	103.1	93.4	97.6	108.0	121.8	63.6	61.8
1988	128.4	126.1	x	126.3	118.3	94.3	103.1	94.3	135.8	68.5	67.3
1989	140.9	137.6	x	127.2	129.3	99.7	110.5	91.1	141.3	70.6	68.9
1990	159.5	152.0	x	130.6	143.3	103.1	118.3	84.7	155.1	74.7	71.1
1991	139.6	197.9	x	74.8	188.6	103.4	140.8	59.3	135.3	70.3	99.7
1992	127.0	146.8	x	87.4	141.9	103.4	119.9	74.6	123.1	78.2	90.4
1993	131.5	129.1	x	101.1	126.5	103.4	113.1	83.7	127.4	85.8	84.2
1994	108.1	115.3	x	93.9	113.2	104.2	107.7	93.3	103.7	99.7	106.4
1995	89.9	95.8	x	94.0	95.0	103.3	99.1	108.2	87.2	133.4	142.2
1996	92.8	100.4	x	92.4	100.1	100.9	100.5	100.5	92.0	115.2	124.6
1997	100.0	100.0	x	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998p	98.8	95.7	x	103.1	95.6	100.3	98.0	104.6	98.5	131.3	127.1
1999p	98.1	100.9	x	96.8	101.4	100.6	101.1	99.2	97.5	105.9	109.0
2000p	96.7	102.1	x	94.2	102.4	101.8	102.2	99.2	95.0	95.9	101.2

p The symbol p means that the series are preliminary.
x The symbol x means that the series has been suppressed for quality reasons.

Table 3b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Fishing and Trapping										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	7.5	1.0	x	6.5	2.1	-6.2	-4.1	-7.2	13.7	7.0	0.5
1983	-3.4	3.6	x	-7.0	4.0	-8.2	-4.9	-11.8	4.8	0.0	7.2
1984	-10.1	4.1	x	-14.2	4.4	-9.2	-5.3	-13.3	-0.9	5.1	21.7
1985	17.2	-2.1	x	19.3	-1.5	-5.6	-4.3	-3.5	22.8	39.8	16.7
1986	3.4	10.0	x	-6.5	10.8	-1.8	2.3	-11.8	5.2	9.2	16.1
1987	-14.1	5.2	x	-19.4	5.7	0.9	2.4	-4.3	-15.0	9.7	34.4
1988	12.4	13.6	x	-1.2	14.7	0.9	5.6	-12.7	11.4	7.7	8.9
1989	9.8	9.1	x	0.7	9.3	5.7	7.2	-3.4	4.1	3.0	2.4
1990	13.2	10.5	x	2.7	10.8	3.5	7.1	-7.0	9.8	5.8	3.2
1991	-12.5	30.2	x	-42.7	31.6	0.2	19.0	-30.0	-12.8	-5.9	40.1
1992	-9.0	-25.8	x	16.8	-24.7	0.0	-14.8	25.8	-9.0	11.3	-9.3
1993	3.5	-12.1	x	15.6	-10.9	0.0	-5.7	12.1	3.5	9.6	-6.9
1994	-17.8	-10.7	x	-7.1	-10.5	0.8	-4.8	11.5	-18.6	16.3	26.4
1995	-16.8	-16.9	x	0.1	-16.0	-0.9	-8.0	16.0	-15.9	33.8	33.7
1996	3.2	4.8	x	-1.6	5.3	-2.3	1.4	-7.1	5.5	-13.7	-12.3
1997	7.8	-0.4	x	8.2	-0.1	-0.9	-0.5	-0.5	8.7	-13.2	-19.8
1998p	-1.2	-4.3	x	3.1	-4.4	0.3	-2.0	4.6	-1.5	31.3	27.1
1999p	-0.7	5.5	x	-6.2	6.0	0.3	3.1	-5.1	-1.0	-19.3	-14.3
2000p	-1.4	1.2	x	-2.6	1.0	1.2	1.1	0.0	-2.6	-9.5	-7.1

p The symbol p means that the series are preliminary.
x The symbol x means that the series has been suppressed for quality reasons.

Table 4a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Logging and Forestry										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	86.5	106.4	x	81.2	96.9	131.2	103.6	129.9	66.9	49.8	61.2
1982	75.6	93.2	x	81.0	86.0	120.8	92.6	135.6	63.8	52.8	65.1
1983	95.5	97.0	x	98.9	90.3	112.2	94.6	120.4	85.0	55.4	56.3
1984	102.4	98.6	x	104.5	92.2	107.7	95.0	113.7	94.6	60.6	58.4
1985	100.0	96.4	x	104.4	90.5	103.8	92.9	112.0	95.8	61.1	58.9
1986	95.4	95.6	x	100.4	90.0	101.0	91.9	109.9	94.0	62.8	63.0
1987	114.7	104.8	x	111.1	99.1	100.0	98.3	98.2	114.0	64.8	59.2
1988	116.2	104.9	x	112.5	99.7	100.5	98.8	98.7	114.9	67.5	60.9
1989	112.3	105.4	x	108.2	100.5	100.0	99.1	97.7	111.6	70.6	66.2
1990	98.6	98.4	x	102.1	94.2	98.5	94.5	102.8	99.6	73.6	73.4
1991	86.1	99.2	x	88.3	95.0	91.3	93.4	94.4	94.3	73.2	84.3
1992	87.6	93.1	x	95.3	90.7	88.8	89.5	97.6	98.5	79.6	84.6
1993	93.4	96.3	x	98.3	94.8	90.8	92.9	96.5	102.7	82.7	85.3
1994	99.1	96.7	x	103.8	95.6	95.0	95.1	100.5	104.3	87.5	85.5
1995	103.2	109.8	x	94.2	108.9	96.3	103.6	88.3	107.2	91.8	97.6
1996	97.3	101.9	x	95.6	101.5	97.0	99.7	95.3	100.3	95.9	100.4
1997	100.0	100.0	x	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998p	98.2	95.3	x	102.9	94.9	102.3	97.8	107.0	95.9	101.9	98.9
1999p	108.0	96.9	x	111.5	96.5	103.0	99.1	105.9	104.8	99.8	89.5
2000p	110.4	105.1	x	104.5	105.3	104.2	105.0	98.3	105.8	107.6	102.5

p The symbol p means that the series are preliminary.
x The symbol x means that the series has been suppressed for quality reasons.

Table 4b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Logging and Forestry										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-12.6	-12.4	x	-0.2	-11.3	-8.0	-10.6	4.4	-4.6	6.1	6.4
1983	26.2	4.1	x	22.2	5.0	-7.1	2.2	-11.2	33.3	5.0	-13.4
1984	7.2	1.6	x	5.6	2.1	-4.0	0.4	-5.6	11.2	9.4	3.7
1985	-2.3	-2.2	x	-0.1	-1.8	-3.7	-2.2	-1.4	1.3	0.8	0.9
1986	-4.6	-0.8	x	-3.8	-0.6	-2.7	-1.1	-1.9	-1.9	2.8	6.9
1987	20.3	9.6	x	10.7	10.1	-1.0	6.9	-10.6	21.3	3.1	-6.0
1988	1.3	0.1	x	1.3	0.6	0.6	0.6	0.5	0.8	4.3	3.0
1989	-3.4	0.5	x	-3.8	0.8	-0.6	0.3	-1.0	-2.8	4.5	8.6
1990	-12.2	-6.7	x	-5.6	-6.2	-1.5	-4.6	5.2	-10.8	4.3	10.9
1991	-12.7	0.8	x	-13.5	0.8	-7.4	-1.2	-8.2	-5.3	-0.5	14.9
1992	1.8	-6.1	x	7.8	-4.6	-2.7	-4.1	3.4	4.4	8.7	0.4
1993	6.6	3.4	x	3.2	4.6	2.3	3.8	-1.1	4.3	3.9	0.8
1994	6.1	0.4	x	5.7	0.8	4.6	2.3	4.2	1.5	5.8	0.2
1995	4.2	13.5	x	-9.3	14.0	1.4	9.0	-12.1	2.8	4.9	14.2
1996	-5.7	-7.2	x	1.5	-6.9	0.8	-3.8	7.9	-6.5	4.5	2.9
1997	2.7	-1.9	x	4.6	-1.4	3.0	0.3	5.0	-0.3	4.3	-0.4
1998p	-1.8	-4.7	x	2.9	-5.1	2.3	-2.2	7.0	-4.1	1.9	-1.1
1999p	10.0	1.6	x	8.3	1.7	0.6	1.3	-1.0	9.3	-2.1	-9.5
2000p	2.2	8.5	x	-6.3	9.1	1.2	6.0	-7.2	1.0	7.9	14.5

p The symbol p means that the series are preliminary.
x The symbol x means that the series has been suppressed for quality reasons.

Table 5a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Mining, Quarrying and Oil Well										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	64.9	100.7	x	65.6	88.5	67.3	71.6	68.1	97.5	47.7	74.0
1982	63.6	97.0	x	66.7	86.5	72.8	76.0	76.2	87.7	55.1	84.0
1983	68.0	93.2	x	73.9	84.2	76.4	78.7	83.0	89.3	59.3	81.2
1984	74.7	98.3	x	77.2	89.6	79.4	82.0	81.6	94.7	62.3	82.0
1985	79.2	102.0	x	78.8	93.8	83.2	86.0	82.5	95.8	65.1	83.9
1986	75.2	97.9	x	78.1	90.8	83.7	85.7	86.2	90.4	66.4	86.5
1987	78.6	94.1	x	84.6	87.6	83.5	84.8	89.5	94.6	66.5	79.7
1988	85.5	97.2	x	89.3	91.3	84.0	86.1	87.0	102.5	71.6	81.3
1989	79.8	96.7	x	83.7	91.6	83.1	85.5	86.5	96.7	74.6	90.4
1990	79.6	94.4	x	85.6	90.5	82.5	84.8	88.0	97.1	78.4	92.9
1991	82.8	94.0	x	89.3	91.1	81.8	84.4	87.5	101.9	84.7	96.3
1992	84.1	87.9	x	96.5	86.2	79.8	81.5	91.1	106.0	86.3	90.2
1993	88.2	83.2	x	106.4	82.3	80.1	80.6	96.3	110.8	89.2	84.2
1994	92.1	90.3	x	102.0	89.5	84.2	85.6	93.0	110.0	90.5	88.8
1995	95.6	94.1	x	101.7	93.6	88.4	89.8	93.8	108.7	91.3	89.8
1996	96.2	96.0	x	100.2	95.5	92.9	93.6	96.6	103.9	96.4	96.2
1997	100.0	100.0	x	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998p	98.4	110.2	x	88.2	109.7	106.0	107.0	95.8	92.5	95.5	106.9
1999p	95.5	102.2	x	91.9	101.8	111.0	108.6	107.2	85.3	99.1	106.1
2000p	101.4	103.9	x	96.2	104.2	116.0	112.8	110.4	86.7	105.1	107.7

p The symbol p means that the series are preliminary.
x The symbol x means that the series has been suppressed for quality reasons.

Table 5b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Mining, Quarrying and Oil Well										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-1.9	-3.7	x	1.7	-2.2	8.2	6.1	11.8	-10.1	15.6	13.6
1983	6.9	-3.9	x	10.8	-2.7	5.0	3.6	8.9	1.9	7.6	-3.3
1984	9.9	5.5	x	4.4	6.4	3.9	4.3	-1.6	6.0	5.1	0.9
1985	6.0	3.8	x	2.2	4.7	4.9	4.8	1.1	1.1	4.5	2.3
1986	-5.0	-4.0	x	-1.0	-3.2	0.6	-0.3	4.6	-5.5	2.0	3.1
1987	4.4	-4.0	x	8.4	-3.6	-0.2	-1.1	3.8	4.6	0.2	-7.9
1988	8.9	3.3	x	5.5	4.2	0.5	1.5	-2.8	8.3	7.6	2.1
1989	-6.7	-0.5	x	-6.2	0.4	-1.0	-0.6	-0.5	-5.7	4.2	11.2
1990	-0.2	-2.4	x	2.2	-1.3	-0.7	-0.8	1.7	0.4	5.1	2.8
1991	4.0	-0.3	x	4.3	0.7	-0.9	-0.5	-0.6	4.9	8.1	3.6
1992	1.6	-6.6	x	8.1	-5.3	-2.5	-3.4	4.1	4.1	1.9	-6.3
1993	4.9	-5.3	x	10.2	-4.5	0.4	-1.1	5.7	4.5	3.3	-6.7
1994	4.5	8.6	x	-4.1	8.7	5.2	6.2	-3.4	-0.7	1.5	5.4
1995	3.8	4.1	x	-0.3	4.6	4.9	4.8	0.8	-1.1	0.8	1.1
1996	0.7	2.1	x	-1.4	2.1	5.0	4.2	3.0	-4.4	5.6	7.1
1997	3.9	4.1	x	-0.2	4.7	7.7	6.9	3.6	-3.8	3.8	4.0
1998p	-1.6	10.2	x	-11.8	9.7	6.0	7.0	-4.2	-7.5	-4.5	6.9
1999p	-3.0	-7.2	x	4.2	-7.2	1.7	1.4	12.0	-7.8	3.8	-0.7
2000p	6.2	1.6	x	4.6	2.4	4.5	3.9	2.9	1.7	6.1	1.5

p The symbol p means that the series are preliminary.
x The symbol x means that the series has been suppressed for quality reasons.

Table 6a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Manufacturing										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	67.8	100.7	81.7	67.4	89.0	73.0	82.6	74.0	93.4	49.6	73.7
1982	61.6	90.7	79.2	67.9	81.3	72.7	77.6	81.0	85.2	56.2	82.8
1983	64.6	89.5	84.2	72.1	80.8	70.4	76.5	79.5	92.1	60.2	83.4
1984	71.9	91.9	91.9	78.3	83.4	70.1	78.0	77.1	102.8	63.6	81.3
1985	75.9	94.6	93.9	80.4	86.4	72.5	80.8	77.4	105.1	66.3	82.6
1986	75.9	98.3	89.9	77.3	90.0	75.6	84.1	77.7	100.6	67.2	87.1
1987	78.9	102.0	89.6	77.4	93.9	78.6	87.7	77.9	100.6	68.8	89.0
1988	85.0	107.8	91.2	79.1	99.9	83.0	93.0	77.8	102.8	71.4	90.5
1989	87.2	106.9	91.5	81.6	99.9	87.5	95.0	82.7	99.7	76.1	93.3
1990	83.0	100.9	89.4	82.3	95.2	88.7	92.7	88.5	93.6	80.8	98.3
1991	77.6	92.4	88.1	83.9	88.1	88.4	88.0	95.7	87.8	86.8	103.4
1992	78.3	88.9	91.2	87.9	85.6	86.7	85.8	97.3	90.4	91.5	103.9
1993	82.9	89.0	96.2	93.0	86.7	85.3	86.0	95.7	97.2	93.3	100.1
1994	89.4	91.6	100.5	97.5	89.7	87.7	88.9	95.7	101.9	94.8	97.2
1995	93.7	94.6	101.5	99.0	93.3	91.2	92.4	96.2	102.9	97.0	97.9
1996	93.7	96.9	98.3	96.5	96.0	94.2	95.2	97.0	99.5	97.9	101.3
1997	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998p	104.1	104.5	99.2	99.6	104.7	105.1	104.9	100.7	98.9	100.7	101.1
1999p	110.4	108.1	100.9	102.3	110.2	108.5	109.5	100.4	101.8	102.4	100.2
2000p	116.5	111.7	102.8	104.5	115.0	111.6	113.5	99.9	104.5	103.8	99.5

p The symbol p means that the series are preliminary.

Table 6b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Manufacturing										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-9.1	-9.9	-3.0	0.8	-8.6	-0.4	-6.1	9.5	-8.7	13.3	12.3
1983	4.9	-1.3	6.3	6.1	-0.6	-3.2	-1.4	-1.9	8.1	7.0	0.7
1984	11.2	2.7	9.2	8.6	3.2	-0.3	2.0	-3.0	11.6	5.7	-2.5
1985	5.6	2.9	2.1	2.7	3.6	3.4	3.5	0.4	2.2	4.2	1.5
1986	-0.1	3.8	-4.3	-3.9	4.1	4.2	4.2	0.4	-4.3	1.5	5.5
1987	4.0	3.8	-0.3	0.2	4.4	4.0	4.3	0.2	0.0	2.4	2.2
1988	7.8	5.7	1.7	2.2	6.4	5.6	6.1	-0.1	2.2	3.8	1.7
1989	2.5	-0.8	0.4	3.3	0.0	5.5	2.1	6.2	-3.0	6.5	3.1
1990	-4.8	-5.6	-2.3	0.9	-4.7	1.4	-2.4	7.0	-6.1	6.2	5.3
1991	-6.6	-8.5	-1.5	1.9	-7.5	-0.3	-5.0	8.1	-6.2	7.4	5.3
1992	1.0	-3.7	3.6	4.7	-2.9	-2.0	-2.6	1.8	3.0	5.4	0.4
1993	5.9	0.1	5.5	5.8	1.3	-1.6	0.3	-1.7	7.5	2.0	-3.6
1994	7.8	2.9	4.5	4.9	3.5	2.9	3.3	0.0	4.9	1.6	-3.0
1995	4.8	3.3	0.9	1.5	3.9	3.9	3.9	0.5	0.9	2.2	0.8
1996	0.0	2.4	-3.1	-2.4	2.9	3.3	3.1	0.9	-3.3	1.0	3.4
1997	6.7	3.1	1.7	3.6	4.2	6.2	5.0	3.0	0.5	2.2	-1.3
1998p	4.1	4.5	-0.8	-0.4	4.7	5.1	4.9	0.7	-1.1	0.7	1.1
1999p	6.1	3.4	1.7	2.7	5.3	3.2	4.4	-0.2	2.9	1.7	-0.9
2000p	5.5	3.4	1.8	2.2	4.3	2.9	3.7	-0.5	2.7	1.3	-0.7

p The symbol p means that the series are preliminary.

Table 7a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Construction										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	93.8	90.8	x	106.3	84.8	81.4	83.7	94.1	115.2	60.9	59.0
1982	92.7	79.9	x	117.8	75.2	81.4	76.6	105.4	113.8	67.5	58.2
1983	91.2	78.1	x	118.4	73.8	80.4	75.2	106.4	113.3	68.2	58.4
1984	87.2	79.1	x	111.9	74.4	80.2	75.7	104.9	108.6	68.0	61.7
1985	92.1	82.3	x	113.6	77.5	80.0	78.0	100.3	115.1	71.9	64.2
1986	96.3	85.0	x	115.1	80.1	82.0	80.5	99.7	117.3	74.9	66.1
1987	101.6	95.4	x	107.3	90.0	85.2	89.0	91.2	119.3	77.8	73.1
1988	104.7	103.2	x	101.8	97.7	89.2	95.9	88.1	117.3	81.6	80.4
1989	110.5	110.4	x	100.4	104.8	93.4	102.4	86.1	118.3	84.9	84.8
1990	110.1	109.0	x	101.3	104.0	95.2	102.2	88.9	115.5	89.0	88.1
1991	100.8	96.7	x	104.2	93.1	94.9	93.4	98.6	106.2	94.2	90.4
1992	94.7	94.0	x	100.8	91.4	95.1	92.0	101.6	99.5	94.6	93.9
1993	91.6	93.1	x	98.4	91.4	95.9	92.2	103.3	95.5	93.5	95.0
1994	94.5	97.7	x	96.7	96.5	97.2	96.6	99.6	97.2	90.8	93.9
1995	91.6	94.5	x	96.9	93.7	96.9	94.2	102.6	94.5	92.4	95.3
1996	94.8	95.6	x	99.2	95.1	96.9	95.3	101.5	97.8	93.8	94.5
1997	100.0	100.0	x	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998p	100.0	101.3	x	98.7	101.0	103.4	101.4	102.1	96.6	105.0	106.3
1999p	104.2	108.7	x	95.6	108.9	107.2	108.6	98.4	97.1	103.7	108.2
2000p	107.6	114.9	x	93.3	114.1	110.9	113.6	96.2	96.9	108.2	115.5

p The symbol p means that the series are preliminary.
x The symbol x means that the series has been suppressed for quality reasons.

Table 7b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Construction										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-1.2	-12.0	x	10.8	-11.3	0.0	-8.4	12.0	-1.2	10.7	-1.4
1983	-1.7	-2.2	x	0.5	-2.0	-1.2	-1.8	1.0	-0.5	1.0	0.5
1984	-4.3	1.2	x	-5.5	0.9	-0.2	0.6	-1.5	-4.1	-0.2	5.5
1985	5.6	4.1	x	1.5	4.1	-0.3	3.1	-4.4	6.0	5.7	4.1
1986	4.5	3.2	x	1.3	3.4	2.6	3.2	-0.6	1.9	4.2	2.9
1987	5.5	12.3	x	-6.8	12.4	3.8	10.5	-8.5	1.7	4.0	10.7
1988	3.0	8.1	x	-5.1	8.5	4.7	7.7	-3.4	-1.7	4.8	10.0
1989	5.6	7.0	x	-1.4	7.3	4.7	6.7	-2.3	0.8	4.1	5.5
1990	-0.4	-1.3	x	0.9	-0.7	2.0	-0.2	3.2	-2.3	4.8	3.8
1991	-8.4	-11.3	x	2.8	-10.5	-0.3	-8.6	10.9	-8.1	5.9	2.6
1992	-6.1	-2.8	x	-3.2	-1.9	0.2	-1.5	3.1	-6.3	0.4	3.9
1993	-3.3	-0.9	x	-2.3	0.1	0.8	0.2	1.7	-4.1	-1.2	1.2
1994	3.2	4.9	x	-1.8	5.5	1.3	4.8	-3.6	1.8	-2.9	-1.2
1995	-3.1	-3.3	x	0.3	-2.9	-0.3	-2.5	3.0	-2.8	1.8	1.5
1996	3.5	1.2	x	2.3	1.5	0.0	1.2	-1.1	3.4	1.5	-0.8
1997	5.5	4.7	x	0.8	5.2	3.2	4.9	-1.5	2.3	6.6	5.8
1998p	0.0	1.3	x	-1.3	1.0	3.4	1.4	2.1	-3.4	5.0	6.3
1999p	4.2	7.3	x	-3.1	7.7	3.7	7.1	-3.6	0.5	-1.2	1.8
2000p	3.3	5.7	x	-2.4	4.9	3.5	4.6	-2.2	-0.2	4.3	6.7

[p] The symbol p means that the series are preliminary.
[x] The symbol x means that the series has been suppressed for quality reasons.

Table 8a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Transportation and Storage										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	57.3	85.2	77.6	67.2	76.1	66.9	73.2	80.9	86.0	59.7	87.8
1982	53.4	77.9	75.4	68.3	70.0	70.4	70.3	92.0	75.6	66.5	96.5
1983	56.7	74.7	81.2	75.4	67.7	72.0	69.3	97.9	78.7	70.8	92.9
1984	63.7	82.1	85.2	77.3	74.5	74.0	74.4	90.8	86.3	70.9	90.8
1985	67.0	85.5	86.6	78.0	78.0	74.6	76.9	87.9	89.9	73.2	92.9
1986	67.4	87.1	85.8	77.0	80.2	74.2	78.1	85.7	90.9	74.2	95.4
1987	71.8	86.7	91.9	82.5	80.2	73.2	77.7	85.0	98.1	76.8	92.3
1988	77.4	88.5	96.8	87.2	82.5	74.7	79.7	85.0	103.8	80.4	91.3
1989	77.4	92.9	92.5	82.9	87.1	76.6	83.3	82.9	101.2	80.7	96.5
1990	77.4	90.2	93.2	85.3	85.4	77.6	82.6	86.5	99.8	85.9	99.3
1991	70.0	86.3	85.5	80.7	82.3	80.2	81.5	93.0	86.9	90.8	111.2
1992	74.4	85.4	89.9	86.6	82.3	82.9	82.4	97.1	89.4	94.1	107.4
1993	78.8	89.8	90.2	87.4	87.6	86.2	87.0	96.0	91.2	91.9	103.9
1994	87.5	94.7	95.7	92.3	92.7	88.8	91.3	93.7	98.5	93.4	100.4
1995	91.1	96.6	96.6	94.2	95.7	91.4	94.2	94.5	99.6	97.6	103.1
1996	95.0	97.8	98.8	97.1	97.3	94.1	96.2	96.1	101.0	95.2	98.1
1997	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998p	103.2	103.9	98.8	99.3	103.7	105.5	104.4	101.6	97.7	100.6	101.4
1999p	108.8	109.8	98.7	99.0	109.4	111.3	110.1	101.4	97.6	102.8	103.9
2000p	114.6	112.3	100.2	102.1	113.2	116.7	114.5	104.0	98.1	106.7	104.7

p The symbol p means that the series are preliminary.

Table 8b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Transportation and Storage										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-6.9	-8.6	-2.9	1.7	-8.0	5.2	-4.0	13.7	-12.0	11.5	9.9
1983	6.3	-4.1	7.7	10.4	-3.3	2.3	-1.5	6.4	4.0	6.4	-3.7
1984	12.4	9.9	4.9	2.5	10.1	2.7	7.5	-7.2	9.7	0.1	-2.3
1985	5.1	4.1	1.7	0.9	4.7	0.9	3.4	-3.2	4.1	3.3	2.3
1986	0.6	1.9	-1.0	-1.3	2.8	-0.6	1.6	-2.5	1.2	1.4	2.7
1987	6.5	-0.5	7.1	7.1	0.0	-1.4	-0.5	-0.8	7.9	3.5	-3.2
1988	7.9	2.1	5.3	5.8	2.8	2.0	2.5	0.0	5.8	4.6	-1.1
1989	0.0	5.0	-4.5	-5.0	5.6	2.5	4.5	-2.5	-2.5	0.5	5.7
1990	0.0	-3.0	0.8	3.0	-2.0	1.4	-0.8	4.4	-1.4	6.3	2.9
1991	-9.6	-4.2	-8.3	-5.4	-3.6	3.3	-1.3	7.6	-12.9	5.7	12.0
1992	6.3	-1.1	5.2	7.3	-0.1	3.4	1.0	4.4	2.9	3.7	-3.4
1993	5.9	5.1	0.3	0.8	6.4	4.0	5.6	-1.2	2.0	-2.4	-3.2
1994	11.1	5.4	6.1	5.7	5.9	3.0	4.9	-2.4	8.0	1.6	-3.3
1995	4.1	2.1	0.9	2.0	3.3	3.0	3.2	0.9	1.1	4.5	2.7
1996	4.3	1.2	2.2	3.1	1.7	2.9	2.1	1.7	1.4	-2.4	-4.8
1997	5.2	2.2	1.2	3.0	2.7	6.3	4.0	4.0	-1.0	5.0	1.9
1998p	3.2	3.9	-1.2	-0.7	3.7	5.5	4.4	1.6	-2.3	0.6	1.4
1999p	5.4	5.7	-0.1	-0.3	5.5	5.5	5.5	-0.2	-0.1	2.2	2.5
2000p	5.4	2.3	1.4	3.1	3.5	4.8	4.0	2.5	0.6	3.8	0.8

p The symbol p means that the series are preliminary.

Table 9a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Communication and Other Utility										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	61.5	79.7	93.7	77.1	70.5	63.2	65.9	79.3	98.4	57.2	74.2
1982	61.4	81.3	88.9	75.4	72.9	66.9	69.1	82.5	92.3	64.2	85.1
1983	64.1	81.3	90.1	78.8	73.8	69.8	71.3	86.1	92.5	68.2	86.5
1984	67.9	81.8	94.5	83.0	74.6	70.5	72.0	86.4	97.0	70.4	84.8
1985	72.1	83.5	99.0	86.3	76.6	70.9	72.9	85.1	102.4	72.9	84.4
1986	74.6	86.1	101.2	86.7	79.2	71.0	73.9	82.6	105.9	74.6	86.0
1987	77.4	87.7	102.6	88.3	81.2	72.7	75.7	82.9	107.4	76.9	87.2
1988	82.3	91.1	104.7	90.4	84.9	75.7	78.9	83.1	109.7	79.6	88.1
1989	83.8	94.7	101.0	88.6	88.7	80.1	83.2	84.8	105.3	82.0	92.6
1990	85.6	96.7	97.5	88.5	91.4	85.8	87.7	88.9	100.1	85.6	96.7
1991	89.5	97.7	97.3	91.6	93.3	91.4	92.0	93.8	98.1	92.4	100.9
1992	89.5	94.8	95.2	94.4	91.8	95.5	94.0	100.8	93.7	97.8	103.6
1993	90.1	96.4	94.1	93.4	94.6	96.5	95.7	100.2	93.4	99.5	106.5
1994	93.0	98.7	96.0	94.2	97.7	96.4	96.8	97.7	96.5	95.4	101.2
1995	96.7	101.1	98.3	95.7	100.8	97.1	98.4	96.1	99.7	98.0	102.4
1996	99.0	100.4	100.3	98.5	100.3	97.7	98.6	97.3	101.3	98.6	100.1
1997	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998p	103.1	102.6	100.5	100.6	102.9	102.5	102.7	99.9	100.6	99.9	99.3
1999p	111.8	100.5	107.9	111.0	100.2	105.6	103.7	104.9	106.1	100.0	89.9
2000p	120.4	106.0	111.7	113.6	106.4	108.9	108.1	102.5	110.9	101.8	89.6

p The symbol p means that the series are preliminary.

Table 9b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Communication and Other Utility										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-0.2	2.0	-5.1	-2.2	3.4	6.0	4.9	4.0	-6.2	12.3	14.7
1983	4.5	0.0	1.4	4.5	1.3	4.3	3.1	4.3	0.2	6.2	1.6
1984	5.9	0.6	4.9	5.3	1.1	1.0	1.0	0.4	4.9	3.3	-1.9
1985	6.1	2.0	4.8	4.1	2.7	0.5	1.3	-1.5	5.5	3.5	-0.5
1986	3.6	3.1	2.2	0.4	3.4	0.2	1.3	-3.0	3.4	2.3	1.9
1987	3.7	1.9	1.4	1.9	2.5	2.3	2.4	0.4	1.4	3.2	1.3
1988	6.3	3.9	2.0	2.4	4.6	4.1	4.3	0.2	2.2	3.4	1.1
1989	1.9	3.9	-3.5	-2.0	4.6	5.9	5.4	2.1	-4.0	3.0	5.0
1990	2.1	2.2	-3.4	-0.1	3.0	7.0	5.5	4.8	-4.9	4.4	4.5
1991	4.6	1.1	-0.3	3.5	2.1	6.5	4.8	5.5	-2.0	7.9	4.3
1992	0.0	-3.0	-2.2	3.0	-1.6	4.5	2.2	7.5	-4.5	5.9	2.7
1993	0.7	1.7	-1.1	-1.0	3.0	1.1	1.8	-0.6	-0.4	1.8	2.8
1994	3.2	2.4	2.1	0.9	3.3	-0.1	1.2	-2.5	3.3	-4.2	-5.0
1995	4.0	2.4	2.4	1.6	3.2	0.7	1.6	-1.7	3.3	2.7	1.1
1996	2.3	-0.6	2.0	2.9	-0.5	0.7	0.3	1.3	1.6	0.7	-2.2
1997	1.0	-0.4	-0.3	1.5	-0.3	2.3	1.4	2.7	-1.3	1.4	-0.1
1998p	3.1	2.6	0.5	0.6	2.9	2.5	2.7	-0.1	0.6	-0.1	-0.7
1999p	8.4	-2.0	7.4	10.4	-2.6	3.0	1.0	5.0	5.4	0.1	-9.5
2000p	7.7	5.4	3.5	2.3	6.2	3.1	4.2	-2.3	4.6	1.8	-0.3

p The symbol p means that the series are preliminary.

Table 10a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Wholesale Trade										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	46.9	72.7	74.0	64.2	64.2	60.2	63.0	83.0	77.6	47.6	73.8
1982	43.4	71.4	69.1	60.6	63.9	59.2	62.6	83.0	73.3	51.5	84.7
1983	47.5	70.9	75.5	66.7	64.0	58.8	62.5	83.1	80.6	56.0	83.6
1984	51.3	73.0	79.7	70.0	66.1	59.1	64.1	81.0	86.5	59.2	84.4
1985	57.0	74.7	86.3	76.2	67.9	61.1	65.9	81.8	93.4	63.1	82.7
1986	62.6	75.9	92.0	82.5	69.4	64.5	68.1	85.2	97.2	68.8	83.4
1987	67.8	79.5	94.4	85.3	73.3	68.1	71.9	85.9	99.8	75.2	88.2
1988	75.1	82.1	100.0	91.8	76.2	72.7	75.4	88.9	103.9	83.0	90.8
1989	79.8	86.5	100.1	92.7	80.8	77.7	80.1	90.2	103.3	86.0	93.2
1990	78.0	88.8	94.0	88.1	83.8	80.9	83.1	91.5	96.8	86.8	98.8
1991	77.9	85.4	95.3	91.4	81.5	82.4	81.8	96.8	94.7	89.6	98.2
1992	80.2	83.2	99.4	96.4	80.2	81.9	80.7	98.5	98.2	92.7	96.2
1993	82.0	82.5	100.4	99.3	80.5	85.3	81.8	103.5	96.2	93.9	94.6
1994	88.6	86.0	105.1	103.1	84.2	85.3	84.5	99.2	103.9	92.7	90.1
1995	89.8	90.2	100.9	99.5	89.0	88.9	89.0	98.5	101.0	95.5	96.0
1996	93.6	94.0	100.2	99.5	93.3	93.7	93.4	99.7	99.8	96.2	96.7
1997	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998p	107.5	102.4	104.3	105.1	102.5	105.3	103.2	103.0	102.2	103.4	98.5
1999p	119.8	109.8	109.0	109.6	109.9	111.8	110.4	101.8	107.6	104.7	95.9
2000p	125.6	113.9	109.3	110.7	114.9	116.4	115.4	102.2	108.3	108.3	98.2

p The symbol p means that the series are preliminary.

Table 10b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Wholesale Trade										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-7.4	-1.8	-6.7	-5.6	-0.4	-1.8	-0.7	0.0	-5.6	8.2	14.7
1983	9.3	-0.7	9.3	10.0	0.2	-0.7	0.0	0.0	10.0	8.7	-1.3
1984	8.0	3.0	5.5	4.9	3.2	0.6	2.5	-2.4	7.4	5.8	0.9
1985	11.2	2.3	8.3	8.9	2.7	3.3	2.9	1.0	7.9	6.5	-2.0
1986	9.8	1.6	6.6	8.2	2.2	5.7	3.3	4.1	4.1	9.0	0.9
1987	8.2	4.7	2.6	3.5	5.6	5.5	5.6	0.8	2.7	9.4	5.8
1988	10.8	3.3	6.0	7.5	4.1	6.8	4.8	3.5	4.0	10.5	2.9
1989	6.3	5.3	0.1	1.0	6.0	6.8	6.2	1.5	-0.6	3.5	2.6
1990	-2.2	2.7	-6.0	-4.9	3.7	4.1	3.8	1.4	-6.3	1.0	6.0
1991	-0.2	-3.9	1.4	3.7	-2.8	1.9	-1.6	5.8	-2.1	3.2	-0.6
1992	3.0	-2.5	4.3	5.5	-1.5	-0.7	-1.3	1.8	3.7	3.4	-2.1
1993	2.2	-0.8	0.9	3.0	0.4	4.2	1.3	5.0	-2.0	1.4	-1.6
1994	8.0	4.2	4.7	3.8	4.5	0.0	3.3	-4.1	8.0	-1.3	-4.8
1995	1.4	4.9	-4.0	-3.5	5.8	4.2	5.4	-0.7	-2.8	3.0	6.6
1996	4.3	4.2	-0.7	0.1	4.8	5.4	5.0	1.2	-1.1	0.7	0.7
1997	6.8	6.4	-0.2	0.5	7.2	6.7	7.0	0.3	0.2	3.9	3.5
1998p	7.5	2.4	4.3	5.1	2.5	5.3	3.2	3.0	2.2	3.4	-1.5
1999p	11.5	7.2	4.5	4.3	7.3	6.1	7.0	-1.1	5.3	1.3	-2.6
2000p	4.8	3.8	0.3	1.0	4.6	4.1	4.5	0.4	0.7	3.4	2.4

p The symbol p means that the series are preliminary.

Table 11a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Retail Trade										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	67.3	80.3	95.6	83.5	73.9	55.6	70.2	69.5	122.4	56.5	67.5
1982	65.6	77.4	95.8	84.6	71.9	54.3	68.4	70.4	122.3	61.0	71.9
1983	66.4	78.6	95.1	84.2	73.5	54.4	69.6	69.5	123.4	62.3	73.7
1984	72.8	82.8	100.4	87.9	77.3	55.0	72.6	66.5	134.1	67.1	76.3
1985	78.1	87.4	102.3	89.4	81.7	57.3	76.4	65.5	138.4	69.8	78.0
1986	81.3	92.3	100.0	88.0	86.8	60.9	81.2	65.9	135.2	72.8	82.7
1987	84.5	92.3	102.1	91.4	87.3	65.1	82.7	70.5	131.2	80.0	87.4
1988	85.7	95.0	99.4	90.2	90.4	69.2	86.1	72.9	124.9	84.1	93.2
1989	86.9	95.3	99.4	91.1	90.9	72.5	87.3	76.2	120.5	88.6	97.1
1990	82.5	96.9	92.1	85.0	92.8	74.8	89.3	77.3	110.7	90.0	105.7
1991	79.1	93.0	90.3	84.9	89.9	76.4	87.4	82.0	103.9	94.9	111.5
1992	80.6	93.5	90.0	86.0	91.3	80.2	89.3	85.6	100.6	94.7	109.9
1993	83.1	93.2	91.6	89.0	91.8	85.2	90.5	91.2	97.5	96.1	107.8
1994	87.8	96.6	92.8	90.8	95.5	89.8	94.4	92.9	97.7	92.9	102.2
1995	91.4	98.1	94.9	93.0	97.1	92.5	96.2	94.3	98.7	93.2	100.1
1996	92.8	97.7	95.7	94.9	97.2	95.6	96.8	97.8	97.0	95.7	100.8
1997	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998p	104.8	100.5	103.4	104.3	100.2	105.7	101.4	105.2	99.1	104.7	100.5
1999p	110.1	101.7	106.3	108.3	101.2	112.9	103.6	111.1	97.3	104.3	96.4
2000p	116.6	103.0	109.1	113.4	103.8	120.0	107.1	116.7	97.1	108.5	95.7

p The symbol p means that the series are preliminary.

Table 11b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Retail Trade										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-2.4	-3.7	0.3	1.3	-2.8	-2.4	-2.7	1.3	0.0	7.8	6.4
1983	1.1	1.6	-0.7	-0.4	2.3	0.2	1.8	-1.3	0.9	2.1	2.6
1984	9.7	5.4	5.5	4.4	5.1	1.1	4.2	-4.3	8.6	7.7	3.4
1985	7.3	5.6	2.0	1.7	5.7	4.1	5.3	-1.5	3.2	4.0	2.3
1986	4.0	5.6	-2.3	-1.6	6.3	6.3	6.3	0.7	-2.3	4.3	6.0
1987	3.9	0.0	2.1	3.9	0.5	6.9	1.8	6.9	-3.0	9.9	5.7
1988	1.5	2.9	-2.7	-1.4	3.6	6.3	4.2	3.4	-4.9	5.2	6.6
1989	1.4	0.3	0.0	1.1	0.5	4.8	1.4	4.6	-3.5	5.3	4.2
1990	-5.1	1.7	-7.3	-6.8	2.1	3.1	2.3	1.4	-8.2	1.6	8.8
1991	-4.1	-4.0	-1.9	-0.1	-3.1	2.1	-2.2	6.1	-6.2	5.4	5.5
1992	1.8	0.6	-0.4	1.2	1.6	5.0	2.2	4.4	-3.2	-0.2	-1.4
1993	3.1	-0.3	1.7	3.5	0.6	6.2	1.4	6.6	-3.1	1.5	-1.9
1994	5.7	3.7	1.4	2.0	4.0	5.5	4.3	1.8	0.2	-3.3	-5.1
1995	4.1	1.5	2.2	2.5	1.7	3.0	1.9	1.5	1.1	0.4	-2.1
1996	1.6	-0.4	0.9	2.0	0.1	3.3	0.7	3.7	-1.7	2.7	0.7
1997	7.7	2.4	4.5	5.4	2.9	4.7	3.3	2.3	3.1	4.4	-0.8
1998p	4.8	0.5	3.4	4.3	0.2	5.7	1.4	5.2	-0.9	4.7	0.5
1999p	5.1	1.2	2.9	3.9	1.0	6.8	2.2	5.6	-1.8	-0.4	-4.0
2000p	6.0	1.2	2.6	4.7	2.6	6.2	3.4	5.0	-0.2	4.0	-0.7

p The symbol p means that the series are preliminary.

Table 12a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Finance, Insurance and Real Estate										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	x	76.3	x	x	63.8	52.0	56.9	67.8	121.3	42.4	x
1982	x	77.0	x	x	65.5	52.7	58.0	68.1	118.3	44.8	x
1983	x	79.1	x	x	68.1	55.6	60.8	69.9	115.7	45.5	x
1984	x	79.8	x	x	69.2	58.2	62.8	72.7	107.6	49.6	x
1985	x	79.5	x	x	69.6	62.0	65.3	77.7	109.0	55.2	x
1986	x	81.7	x	x	72.0	66.1	68.6	80.6	107.5	58.0	x
1987	x	85.5	x	x	76.0	72.8	74.2	85.1	101.7	63.5	x
1988	x	89.4	x	x	80.1	77.8	78.8	87.0	92.5	68.0	x
1989	x	91.5	x	x	82.7	83.7	83.2	91.5	87.1	71.7	x
1990	x	92.5	x	x	84.8	88.2	86.6	95.4	84.8	74.1	x
1991	x	93.1	x	x	86.6	90.8	88.8	97.8	84.3	78.9	x
1992	x	92.3	x	x	87.5	91.9	89.8	99.8	85.7	82.1	x
1993	x	93.3	x	x	90.3	92.1	91.2	98.9	89.3	84.6	x
1994	x	95.3	x	x	93.4	92.4	92.8	97.1	96.3	83.7	x
1995	x	94.0	x	x	92.9	95.1	94.1	101.2	96.6	86.5	x
1996	x	97.4	x	x	96.7	97.1	96.9	99.7	96.9	90.6	x
1997	x	100.0	x	x	100.0	100.0	100.0	100.0	100.0	100.0	x
1998p	x	97.7	x	x	97.3	103.2	100.5	105.5	99.8	109.3	x
1999p	x	99.8	x	x	97.7	107.8	103.1	107.9	97.8	115.3	x
2000p	x	103.2	x	x	102.5	112.0	107.6	108.4	99.7	128.7	x

p The symbol p means that the series are preliminary.
x The symbol x means that the series has been suppressed for quality reasons.

Table 12b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Finance, Insurance and Real Estate										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	x	0.9	x	x	2.7	1.4	2.0	0.4	-2.5	5.6	x
1983	x	2.7	x	x	3.9	5.4	4.8	2.7	-2.2	1.7	x
1984	x	0.8	x	x	1.6	4.8	3.4	3.9	-7.0	9.0	x
1985	x	-0.3	x	x	0.6	6.6	3.9	6.9	1.3	11.3	x
1986	x	2.7	x	x	3.4	6.5	5.1	3.8	-1.3	5.1	x
1987	x	4.7	x	x	5.5	10.2	8.1	5.5	-5.5	9.4	x
1988	x	4.6	x	x	5.4	6.8	6.2	2.3	-9.0	7.1	x
1989	x	2.3	x	x	3.2	7.5	5.5	5.1	-5.8	5.5	x
1990	x	1.1	x	x	2.5	5.4	4.1	4.3	-2.6	3.4	x
1991	x	0.6	x	x	2.1	3.0	2.6	2.4	-0.7	6.4	x
1992	x	-0.8	x	x	1.0	1.2	1.1	2.0	1.8	4.0	x
1993	x	1.0	x	x	3.2	0.2	1.6	-0.9	4.1	3.1	x
1994	x	2.1	x	x	3.5	0.3	1.8	-1.8	7.9	-1.1	x
1995	x	-1.3	x	x	-0.5	2.9	1.4	4.2	0.4	3.4	x
1996	x	3.6	x	x	4.0	2.1	3.0	-1.4	0.2	4.8	x
1997	x	2.7	x	x	3.4	3.0	3.2	0.3	3.2	10.3	x
1998p	x	-2.3	x	x	-2.7	3.2	0.5	5.5	-0.2	9.3	x
1999p	x	2.2	x	x	0.4	4.4	2.6	2.3	-2.0	5.5	x
2000p	x	3.4	x	x	4.9	3.9	4.4	0.5	1.9	11.6	x

[p] The symbol p means that the series are preliminary.
[x] The symbol x means that the series has been suppressed for quality reasons.

Table 13a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Business Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	x	48.5	x	x	40.7	13.7	33.6	27.0	433.5	50.9	x
1982	x	47.8	x	x	41.2	13.8	34.0	27.6	447.6	57.9	x
1983	x	47.1	x	x	41.5	14.6	34.6	29.5	393.7	58.5	x
1984	x	50.8	x	x	45.1	16.4	37.8	30.9	380.8	61.0	x
1985	x	54.9	x	x	49.4	18.6	41.7	32.5	347.0	64.1	x
1986	x	60.2	x	x	54.5	21.1	46.2	33.8	332.3	65.1	x
1987	x	65.0	x	x	59.2	24.7	51.0	36.8	311.3	69.4	x
1988	x	70.0	x	x	64.3	29.1	56.3	40.5	289.2	76.2	x
1989	x	74.9	x	x	69.6	33.8	61.7	44.2	256.1	81.1	x
1990	x	75.3	x	x	70.8	37.1	63.6	48.3	235.5	87.3	x
1991	x	76.2	x	x	73.0	41.7	66.5	53.7	204.0	89.2	x
1992	x	73.6	x	x	71.6	49.1	67.1	65.0	159.6	92.5	x
1993	x	76.3	x	x	75.4	52.8	71.0	67.7	155.9	93.6	x
1994	x	79.8	x	x	79.5	64.3	76.7	79.2	131.0	95.1	x
1995	x	85.1	x	x	84.8	71.6	82.4	82.9	126.0	95.8	x
1996	x	92.0	x	x	91.5	84.9	90.4	91.7	107.0	95.9	x
1997	x	100.0	x	x	100.0	100.0	100.0	100.0	100.0	100.0	x
1998p	x	109.8	x	x	109.8	121.0	111.5	111.2	87.4	105.3	x
1999p	x	121.7	x	x	120.0	147.7	124.1	123.6	75.5	107.3	x
2000p	x	127.4	x	x	128.8	177.9	135.8	143.2	67.5	124.4	x

p The symbol p means that the series are preliminary.
x The symbol x means that the series has been suppressed for quality reasons.

Table 13b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Business Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	x	-1.5	x	x	1.2	0.4	1.0	1.9	3.3	13.7	x
1983	x	-1.5	x	x	0.8	5.8	1.8	7.2	-12.0	1.1	x
1984	x	7.9	x	x	8.6	12.5	9.4	4.6	-3.3	4.2	x
1985	x	8.1	x	x	9.5	13.2	10.2	5.1	-8.9	5.1	x
1986	x	9.6	x	x	10.3	13.6	10.9	4.0	-4.2	1.6	x
1987	x	8.0	x	x	8.7	16.9	10.3	8.9	-6.3	6.6	x
1988	x	7.6	x	x	8.7	17.6	10.3	9.9	-7.1	9.7	x
1989	x	7.1	x	x	8.1	16.4	9.6	9.3	-11.5	6.4	x
1990	x	0.5	x	x	1.8	9.8	3.1	9.2	-8.0	7.6	x
1991	x	1.1	x	x	3.1	12.3	4.5	11.1	-13.4	2.3	x
1992	x	-3.4	x	x	-1.9	17.8	1.0	21.1	-21.7	3.6	x
1993	x	3.6	x	x	5.4	7.6	5.7	4.0	-2.3	1.2	x
1994	x	4.6	x	x	5.4	21.8	8.1	17.1	-16.0	1.6	x
1995	x	6.7	x	x	6.6	11.4	7.4	4.7	-3.8	0.7	x
1996	x	8.1	x	x	7.9	18.6	9.7	10.5	-15.1	0.1	x
1997	x	8.7	x	x	9.3	17.8	10.6	9.1	-6.5	4.3	x
1998p	x	9.8	x	x	9.8	21.0	11.5	11.2	-12.6	5.3	x
1999p	x	10.9	x	x	9.3	22.1	11.3	11.2	-13.6	1.9	x
2000p	x	4.6	x	x	7.4	20.4	9.4	15.8	-10.6	15.9	x

p The symbol p means that the series are preliminary.
x The symbol x means that the series has been suppressed for quality reasons.

Table 14a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Educational Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	x	22.0	x	x	17.7	22.3	17.7	153.7	120.7	59.2	x
1982	x	24.7	x	x	19.5	24.0	19.5	146.2	121.3	57.4	x
1983	x	29.2	x	x	23.0	27.1	22.9	138.4	110.9	53.0	x
1984	x	29.9	x	x	23.5	32.8	23.7	164.0	92.3	54.4	x
1985	x	32.0	x	x	25.3	39.3	25.8	185.1	73.7	55.0	x
1986	x	35.9	x	x	28.6	44.3	29.2	186.1	64.0	52.9	x
1987	x	40.9	x	x	31.4	50.7	32.2	187.3	53.2	47.0	x
1988	x	39.3	x	x	31.3	59.1	32.5	225.6	44.9	52.6	x
1989	x	37.5	x	x	30.7	63.8	32.1	254.1	41.6	59.0	x
1990	x	46.1	x	x	35.7	67.8	37.1	211.4	41.0	54.1	x
1991	x	43.9	x	x	34.4	74.7	36.2	243.0	34.0	60.8	x
1992	x	42.8	x	x	34.2	78.8	36.1	262.8	33.5	65.1	x
1993	x	53.3	x	x	42.4	82.3	44.3	209.9	32.2	55.9	x
1994	x	52.6	x	x	43.6	92.6	45.8	238.7	27.3	57.4	x
1995	x	55.2	x	x	45.2	94.0	47.5	230.8	27.0	54.7	x
1996	x	84.4	x	x	83.2	99.5	85.2	121.9	69.5	103.0	x
1997	x	100.0	x	x	100.0	100.0	100.0	100.0	100.0	100.0	x
1998p	x	119.8	x	x	119.4	100.5	115.7	80.7	119.3	94.5	x
1999p	x	116.5	x	x	116.4	102.7	113.6	84.7	144.9	83.4	x
2000p	x	120.6	x	x	119.5	105.3	116.6	83.8	168.9	93.9	x

p The symbol p means that the series are preliminary.
x The symbol x means that the series has been suppressed for quality reasons.

Table 14b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Educational Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	x	12.4	x	x	10.1	7.6	9.9	-4.9	0.5	-3.0	x
1983	x	18.2	x	x	17.8	12.9	17.4	-5.3	-8.5	-7.7	x
1984	x	2.4	x	x	2.2	20.9	3.8	18.5	-16.8	2.7	x
1985	x	7.0	x	x	7.7	19.9	8.7	12.9	-20.2	1.1	x
1986	x	12.3	x	x	13.2	12.8	13.2	0.6	-13.2	-3.8	x
1987	x	13.7	x	x	9.9	14.3	10.3	0.6	-16.8	-11.1	x
1988	x	-3.7	x	x	-0.3	16.7	1.1	20.5	-15.6	11.8	x
1989	x	-4.7	x	x	-2.1	7.9	-1.3	12.6	-7.2	12.1	x
1990	x	23.0	x	x	16.4	6.2	15.4	-16.8	-1.5	-8.2	x
1991	x	-4.8	x	x	-3.6	10.2	-2.4	14.9	-17.0	12.3	x
1992	x	-2.6	x	x	-0.7	5.6	-0.2	8.1	-1.5	7.1	x
1993	x	24.6	x	x	24.2	4.4	22.6	-20.1	-3.9	-14.0	x
1994	x	-1.3	x	x	2.6	12.5	3.4	13.7	-15.3	2.6	x
1995	x	4.9	x	x	3.8	1.6	3.6	-3.3	-0.8	-4.7	x
1996	x	53.0	x	x	84.1	5.9	79.6	-47.2	156.9	88.5	x
1997	x	18.4	x	x	20.2	0.5	17.4	-18.0	43.9	-2.9	x
1998p	x	19.8	x	x	19.4	0.5	15.7	-19.3	19.3	-5.5	x
1999p	x	-2.7	x	x	-2.5	2.2	-1.8	5.0	21.5	-11.8	x
2000p	x	3.5	x	x	2.6	2.5	2.6	-1.0	16.6	12.6	x

p The symbol p means that the series are preliminary.
x The symbol x means that the series has been suppressed for quality reasons.

Table 15a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Health and Social Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	x	42.6	x	x	45.6	69.5	49.7	170.2	92.3	58.4	x
1982	x	45.6	x	x	49.1	70.2	52.7	160.2	93.4	64.1	x
1983	x	47.9	x	x	50.4	71.6	54.0	155.3	94.4	69.3	x
1984	x	51.6	x	x	55.7	73.0	58.6	146.4	96.0	73.2	x
1985	x	54.3	x	x	58.8	75.2	61.6	143.1	96.1	77.7	x
1986	x	56.8	x	x	59.2	77.7	62.4	141.2	97.8	78.8	x
1987	x	62.8	x	x	65.9	80.6	68.3	131.5	96.6	78.4	x
1988	x	69.6	x	x	72.7	83.1	74.3	121.3	97.9	78.3	x
1989	x	69.8	x	x	71.0	85.8	73.4	125.1	99.8	85.2	x
1990	x	73.5	x	x	75.4	88.3	77.5	121.9	100.6	90.3	x
1991	x	78.9	x	x	79.6	88.6	80.9	113.4	104.0	91.0	x
1992	x	82.2	x	x	82.1	89.7	83.2	110.1	105.6	94.2	x
1993	x	88.9	x	x	91.4	89.2	90.7	100.6	104.1	92.5	x
1994	x	90.2	x	x	90.8	92.1	90.7	102.2	102.3	94.3	x
1995	x	90.9	x	x	86.8	94.7	87.9	104.4	99.5	95.2	x
1996	x	93.4	x	x	90.3	96.2	91.1	103.2	97.8	97.7	x
1997	x	100.0	x	x	100.0	100.0	100.0	100.0	100.0	100.0	x
1998p	x	96.9	x	x	101.8	102.2	101.8	105.3	100.0	109.8	x
1999p	x	108.6	x	x	113.5	104.8	112.3	95.3	99.1	100.4	x
2000p	x	112.8	x	x	116.9	107.4	115.5	93.9	98.7	108.9	x

p The symbol p means that the series are preliminary.
x The symbol x means that the series has been suppressed for quality reasons.

Table 15b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Health and Social Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	x	7.0	x	x	7.6	1.0	5.9	-5.9	1.1	9.7	x
1983	x	4.9	x	x	2.8	1.9	2.6	-3.0	1.1	8.2	x
1984	x	7.8	x	x	10.5	2.0	8.5	-5.8	1.7	5.6	x
1985	x	5.2	x	x	5.6	3.0	5.1	-2.2	0.1	6.3	x
1986	x	4.7	x	x	0.7	3.3	1.2	-1.3	1.7	1.4	x
1987	x	10.6	x	x	11.2	3.8	9.5	-6.9	-1.1	-0.5	x
1988	x	10.8	x	x	10.5	3.1	8.8	-7.7	1.3	-0.2	x
1989	x	0.2	x	x	-2.4	3.3	-1.2	3.1	1.9	8.8	x
1990	x	5.4	x	x	6.2	2.8	5.5	-2.5	0.8	6.0	x
1991	x	7.4	x	x	5.5	0.4	4.4	-7.0	3.4	0.8	x
1992	x	4.1	x	x	3.2	1.2	2.8	-2.9	1.6	3.5	x
1993	x	8.1	x	x	11.3	-0.6	9.0	-8.6	-1.4	-1.8	x
1994	x	1.5	x	x	-0.7	3.2	0.0	1.7	-1.7	1.9	x
1995	x	0.7	x	x	-4.3	2.8	-3.1	2.1	-2.7	1.0	x
1996	x	2.7	x	x	4.0	1.6	3.6	-1.1	-1.8	2.6	x
1997	x	7.1	x	x	10.7	3.9	9.8	-3.1	2.3	2.3	x
1998p	x	-3.1	x	x	1.8	2.2	1.8	5.3	0.0	9.8	x
1999p	x	12.1	x	x	11.6	2.5	10.3	-9.5	-0.9	-8.6	x
2000p	x	3.9	x	x	3.0	2.4	2.9	-1.4	-0.4	8.4	x

[p] The symbol p means that the series are preliminary.
[x] The symbol x means that the series has been suppressed for quality reasons.

Table 16a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Accommodation, Food and Beverage Services										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	x	81.5	x	x	77.6	57.8	72.3	71.4	167.7	53.2	x
1982	x	77.2	x	x	73.8	57.9	69.7	75.3	153.7	58.8	x
1983	x	80.1	x	x	76.6	58.8	71.9	73.6	148.2	60.0	x
1984	x	79.7	x	x	76.4	61.5	72.5	77.4	145.0	64.4	x
1985	x	83.0	x	x	79.0	65.6	75.5	79.3	141.2	67.5	x
1986	x	86.4	x	x	83.3	70.4	79.9	82.0	130.9	68.7	x
1987	x	93.1	x	x	89.9	77.7	86.6	84.0	120.4	68.8	x
1988	x	93.4	x	x	90.6	86.1	89.2	92.9	111.3	75.0	x
1989	x	97.2	x	x	94.7	93.3	94.0	96.8	109.0	81.1	x
1990	x	97.5	x	x	93.9	97.5	94.3	100.9	104.9	84.2	x
1991	x	91.7	x	x	88.9	102.5	91.5	112.0	85.5	87.1	x
1992	x	91.0	x	x	89.0	102.4	91.6	112.8	86.2	91.6	x
1993	x	94.5	x	x	93.2	102.1	94.9	108.1	88.6	90.8	x
1994	x	97.3	x	x	95.3	102.7	96.8	105.6	91.3	92.1	x
1995	x	97.1	x	x	96.0	99.3	96.7	102.3	97.6	96.4	x
1996	x	98.5	x	x	97.7	98.1	97.8	99.6	99.1	96.2	x
1997	x	100.0	x	x	100.0	100.0	100.0	100.0	100.0	100.0	x
1998p	x	107.0	x	x	105.9	101.4	105.0	94.4	105.5	100.2	x
1999p	x	108.2	x	x	107.1	104.6	106.6	96.3	104.3	100.0	x
2000p	x	113.1	x	x	110.6	107.5	110.0	94.6	105.1	103.5	x

p The symbol p means that the series are preliminary.
x The symbol x means that the series has been suppressed for quality reasons.

Table 16b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Accommodation, Food and Beverage Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	x	-5.3	x	x	-4.9	0.3	-3.7	5.6	-8.4	10.7	x
1983	x	3.8	x	x	3.8	1.6	3.3	-2.3	-3.6	2.1	x
1984	x	-0.6	x	x	-0.3	4.6	0.7	5.1	-2.2	7.3	x
1985	x	4.2	x	x	3.5	6.6	4.2	2.4	-2.6	4.8	x
1986	x	4.0	x	x	5.4	7.4	5.8	3.4	-7.3	1.7	x
1987	x	7.8	x	x	7.8	10.2	8.4	2.4	-8.1	0.2	x
1988	x	0.3	x	x	0.8	10.9	3.0	10.6	-7.5	9.0	x
1989	x	4.0	x	x	4.5	8.3	5.4	4.3	-2.1	8.0	x
1990	x	0.3	x	x	-0.9	4.5	0.3	4.2	-3.7	3.9	x
1991	x	-5.9	x	x	-5.3	5.2	-3.0	11.1	-18.5	3.5	x
1992	x	-0.8	x	x	0.2	-0.1	0.1	0.7	0.9	5.1	x
1993	x	3.9	x	x	4.7	-0.3	3.7	-4.2	2.7	-0.9	x
1994	x	2.9	x	x	2.3	0.6	1.9	-2.3	3.1	1.4	x
1995	x	-0.1	x	x	0.7	-3.3	-0.1	-3.1	6.9	4.7	x
1996	x	1.4	x	x	1.8	-1.2	1.1	-2.6	1.5	-0.2	x
1997	x	1.5	x	x	2.3	1.9	2.3	0.4	0.9	3.9	x
1998p	x	7.0	x	x	5.9	1.4	5.0	-5.6	5.5	0.2	x
1999p	x	1.2	x	x	1.1	3.1	1.5	2.0	-1.1	-0.2	x
2000p	x	4.5	x	x	3.3	2.7	3.2	-1.7	0.8	3.5	x

[p] The symbol p means that the series are preliminary.
[x] The symbol x means that the series has been suppressed for quality reasons.

Table 17a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Other Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	66.3	64.4	x	104.3	60.3	40.9	53.4	63.2	170.1	53.6	52.0
1982	64.8	62.8	x	104.6	59.1	40.6	52.6	64.2	167.6	58.8	56.9
1983	64.3	65.2	x	99.6	61.2	42.9	54.8	65.3	157.0	60.0	60.9
1984	67.2	66.3	x	102.5	62.5	46.3	56.9	69.5	151.4	64.2	63.4
1985	71.6	74.5	x	96.5	69.3	52.4	63.4	69.9	141.7	64.5	67.1
1986	75.2	74.5	x	101.4	71.0	58.7	66.9	78.4	131.6	70.0	69.3
1987	78.4	78.2	x	100.6	74.6	67.2	72.2	85.8	118.1	73.7	73.5
1988	86.7	83.4	x	104.6	80.3	75.2	78.7	90.3	116.5	79.4	76.4
1989	86.6	84.8	x	102.7	82.7	81.5	82.3	96.4	106.6	81.7	80.0
1990	86.6	86.6	x	100.5	83.6	84.8	83.9	98.3	102.2	85.9	85.9
1991	84.8	85.0	x	100.4	82.1	84.3	82.7	99.5	100.8	89.9	90.1
1992	85.4	83.6	x	102.7	81.3	86.0	82.6	103.1	99.5	93.6	91.7
1993	87.1	88.6	x	98.6	85.6	89.6	86.7	101.3	97.3	90.8	92.4
1994	90.1	92.9	x	97.2	90.8	94.2	91.7	101.6	95.6	90.9	93.8
1995	93.4	93.6	x	100.0	92.4	93.1	92.6	99.6	100.2	95.2	95.5
1996	93.7	98.9	x	94.7	97.8	95.3	97.1	96.3	98.2	94.9	100.2
1997	100.0	100.0	x	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998p	102.9	102.5	x	100.3	103.0	104.7	103.5	102.1	98.2	107.9	107.5
1999p	105.1	107.3	x	97.9	108.8	109.8	109.1	102.4	95.6	106.0	108.2
2000p	107.7	107.4	x	100.1	108.6	113.9	110.2	106.1	94.3	113.9	113.6

p The symbol p means that the series are preliminary.
x The symbol x means that the series has been suppressed for quality reasons.

Table 17b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Other Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-2.2	-2.5	x	0.3	-1.9	-0.7	-1.6	1.7	-1.5	9.7	9.4
1983	-0.8	3.9	x	-4.8	3.6	5.5	4.1	1.6	-6.3	2.1	7.0
1984	4.5	1.7	x	2.8	2.0	8.1	3.8	6.4	-3.6	7.0	4.1
1985	6.6	12.4	x	-5.8	11.0	13.0	11.6	0.6	-6.4	0.5	5.9
1986	5.0	-0.1	x	5.0	2.5	12.1	5.4	12.2	-7.1	8.5	3.3
1987	4.3	5.0	x	-0.8	5.1	14.5	8.0	9.5	-10.3	5.3	6.0
1988	10.6	6.7	x	3.9	7.6	11.9	8.9	5.3	-1.3	7.8	3.9
1989	-0.1	1.6	x	-1.8	3.0	8.4	4.6	6.8	-8.5	3.0	4.8
1990	-0.1	2.1	x	-2.2	1.1	4.0	2.0	1.9	-4.1	5.1	7.4
1991	-2.0	-1.9	x	-0.2	-1.7	-0.6	-1.4	1.2	-1.4	4.7	4.9
1992	0.8	-1.6	x	2.3	-1.1	2.0	-0.2	3.6	-1.3	4.1	1.7
1993	1.9	5.9	x	-4.0	5.4	4.2	5.0	-1.8	-2.2	-3.0	0.8
1994	3.4	4.8	x	-1.4	6.0	5.1	5.8	0.3	-1.7	0.1	1.5
1995	3.7	0.8	x	2.9	1.8	-1.1	0.9	-2.0	4.8	4.7	1.8
1996	0.3	5.6	x	-5.3	5.9	2.4	4.9	-3.3	-2.0	-0.3	4.9
1997	6.7	1.1	x	5.6	2.2	4.9	3.0	3.8	1.8	5.4	-0.2
1998p	2.9	2.5	x	0.3	3.0	4.7	3.5	2.1	-1.8	7.9	7.5
1999p	2.2	4.6	x	-2.4	5.6	4.9	5.4	0.2	-2.7	-1.7	0.6
2000p	2.4	0.2	x	2.3	-0.1	3.8	1.1	3.6	-1.3	7.4	5.0

p The symbol p means that the series are preliminary.
x The symbol x means that the series has been suppressed for quality reasons.

Glossary

This glossary provides basic definitions of the terms used in measuring productivity. These terms are essential for a clear understanding of some parts of this publication. Further explanations of many of these terms can be found in the text.

Annual average number of hours worked in all jobs. The annual average of hours worked for jobs in all categories.

Business capital investment. Expenditure on assets having a productive life of more than one year (e.g., machinery and equipment). More precisely, it is an expenditure designed to maintain or improve productive capacity. Business capital investment should not be confused with intermediate inputs, which are consumed or transformed during a relatively short production cycle.

Business sector. Productivity measures exclude all non-commercial activities as well as the rental value of owner-occupied dwellings. Corresponding exclusions are also made to compensation and hours worked. In 1992, business sector GDP accounted for about 71% of the Canadian total. The business sector is further divided into the goods sector and the services sector.

Business sector goods industries. Consists of agriculture, fishing, forestry, mining activities, manufacturing, construction and public utilities.

Business sector services industries. Consists of transportation and storage, communications, wholesale and retail trade, finance, insurance and real estate, and the group formed by community, business and personal services.

Chain indices. Indices calculated for consecutive periods to determine price or volume changes from one period to another. Price and volume variations between successive periods are calculated by combining their short-term movement, i.e., by linking the indices for consecutive periods so as to form chain indices.

Choice of the productivity measures. In calculating productivity, a variety of measures of production (and thus factors of production) can be used: value added, gross output and gross output less intra-industry sales. The choice of a measure of productivity will naturally depend on the user's analytical needs. For example, a measure based on value added is interesting because it not only allows international comparisons, but also eliminates double counting when measuring industrial activity.

Combined inputs. A weighted sum of factors of production, particularly labour and capital. The weighting used to combine labour, capital and sometimes other factors (such as energy, raw materials and services) corresponds to the cost share for each factor with respect to total revenue for the sector.

Factors of production. The economic resources used in a firm's production process. A distinction is usually drawn between two primary factors (labour and capital) and intermediate inputs (energy and raw materials). The term 'inputs' is often used to refer to the factors of production.

Fisher chain index. The geometric mean of the Laspeyres and Paasche chain indices. The Fisher chain index treats two compared periods symmetrically. The real GDP indices to determine variations in quantity for the measurement of productivity are based on Fisher chain indices. These offer the advantage of reducing the variation in the values recorded by the various fixed-base indices.

Fixed capital stock. The stock of machinery, equipment, structures (buildings and engineering construction) and tenant-occupied dwellings.

Full-time equivalent employment (FTE). The number of FTEs is the ratio of the number of hours worked in all jobs to the average number of hours worked per year in full-time jobs. This variable is particularly useful in international comparisons with countries that do not have a statistical device to estimate hours worked in all jobs.

GDP at basic prices. The GDP at factor costs *plus* production taxes *less* subsidies.

GDP at factor costs. The measure of GDP corresponding to the value of combined inputs in labour and capital that must be paid by the producer for use of these factors of production. This measure excludes indirect taxes and subsidies.

Gross domestic product (GDP). The total value of goods and services produced within a country's borders, over a given period, regardless of the nationality of the factors of production.

Hours worked in all jobs. The number of hours worked in all jobs is the annual average for all jobs times the annual average hours worked in all jobs. Hours worked is the total number of hours that a person spends working, whether paid or not. In general, this includes regular and overtime hours, breaks, travel time, training in the workplace and time lost in brief work stoppages where workers remain at their posts. It does not include time lost to strikes, lockouts, annual vacation, public holidays, sick leave, maternity leave or leave for personal needs.

Hours worked in all paid jobs. The average number of paid workers during the year multiplied by the annual average number of hours worked in paid jobs.

Industry activity sector. A group of production units all having the same main activity.

Job-to-population ratio. The ratio of the total number of jobs to overall population.

Labour productivity (GDP per hour worked). The ratio of output to hours worked. Economic performance as measured by labour productivity must be interpreted carefully, as these estimates reflect growth in productivity efficiency and changes in other factors of production (such as capital).

Multifactor productivity. A measure of productivity growth, taking into account many of the resources used in the activity of production. Multifactor productivity growth is estimated residually as the difference between the growth rate of output and the growth rate of combined inputs.

Output. The final product of the activity of production obtained from the combination of resources such as labour, capital, materials, services and energy.

Paid jobs. Jobs held by workers whose base pay is calculated at an hourly rate, or on the basis of a fixed amount for a period of at least a week, or in the form of sales commission, piece rates, mileage allowances and so on.

Productivity index. The ratio of the output index to the combined inputs index; the output and the combined inputs are evaluated at constant prices. Expressing productivity levels using indices facilitates comparison and analysis with respect to a base year.

Real GDP per capita. Often used as an indicator of the evolution of a population's standard of living, it is calculated as the real value of production of goods and services divided by total population.

Real GDP per job. An alternate measure of labour productivity. This is calculated by dividing GDP measured in real terms by the total number of jobs. Since this basic definition of labour productivity does not take into consideration time worked, which varies over time and from worker to worker, it is less accurate than the measure of GDP per hour worked. However, this measure can be useful for comparisons with real GDP per capita and is sometimes used to complement productivity analysis.

Total compensation per hour worked or **hourly compensation.** The ratio of the total compensation for all jobs to the number of hours worked.

Total compensation per job. The ratio of the total compensation for all jobs to the total number of jobs.

Total labour compensation. All payments in cash or in kind made by domestic producers to workers for services rendered—in other words, total payroll. It includes the salaries and supplementary labour income of paid workers, plus an imputed labour income for self-employed workers.

Total number of jobs. An estimate that covers four main categories: paid jobs, work for unincorporated businesses, self-employment, and unpaid family jobs. The last category is found mainly in sectors where family firms are important (agriculture and retail trade in particular). Until recently, self-employment and work for an unincorporated business were grouped together as self-employment.

Unit labour cost. The labour cost per unit of output. It equals labour compensation divided by real GDP. It is also equal to the ratio of labour compensation per hour worked to labour productivity. Unit labour cost increases when labour compensation per hour worked increases more rapidly than labour productivity. It is widely used to measure inflation pressures arising from wage growth.

Value added. A measure of production in the same way as is gross output. However, it has the advantage of eliminating double counting. An industry's value added is equal to its gross output (mainly sales) less its intermediate consumption (energy, raw materials and services). Total value added, over all industries, is equal to the GDP at current price for all industries. In order to compare production between different years, it is necessary to eliminate the effect of price change. Therefore, the change in produced quantities only is estimated from the value added in real terms, that is, the value added of a certain period measured in prices of the other period, usually a previous year. This year called the base year (e.g., 1992), is written as '1992=100'. The double-deflation procedure is used to measure real value added: real intermediate inputs are subtracted from real gross output.

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Canadian Productivity Accounts Data

For a limited time, Statistics Canada is making available to purchasers of *Productivity Growth in Canada 2002, 15-204-XPE* the database which it uses to calculate various measures of multifactor productivity. This database, known as KLEMS, is now available on a CD Rom available free of charge for those who purchase *Productivity Growth in Canada*. Users interested in this database should send a request to productivity.measures@statcan.ca.

The database contains volume and price series on inputs and production expressed as Fisher-chained indices (1992=100), as well as the dollar cost of inputs. Price and quantity indices cover capital services, labour services, energy, materials and services, considered individually or in terms of primary inputs (capital and labour), intermediate inputs (energy, materials and services) or total input. Gross-output and value-added price and quantity indices, two alternate measures of production, are also available.

These data cover 48 industries of Canadian business sector 1981 to1997.

In addition to measuring multifactor productivity, the integrated database offers a potential for examining different subjects relating to economic performance and industrial-structure.

Productivity Growth in Canada

Completely revamped for 2000, **Productivity Growth in Canada** formerly called Aggregate Productivity Measures is the ultimate source for productivity trends, measures and growth of Canadian businesses in domestic and international markets.

An invaluable tool, **Productivity Growth in Canada** contains:

- Highly informative articles
- In-depth analysis
- Stylized facts on productivity at the plant, industry and business sector levels.

This edition includes articles that describe:

- How multifactor productivity estimates have been revised to take into account the latest in current methodology.
- The new techniques and estimates of depreciation of capital stock.
- New estimates of labour growth that takes into account skill levels of workers.
- New estimates of capital services.
- The importance of unit labour cost measures when it comes to understanding trends in Canada's competitiveness.